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MEMORANDUM REPORT NO. 1362
AUGUST 1961

SATELLITE-INDUCED IONIZATION
OBSERVED WITH THE DOPLOC SYSTEM

ARPA Satellite Fence Series

Harold T. Lootens

Report No. 23 in the Series

Department of the Army Project No. 503-06-011
Ordnance Management Structure Code No. 5210.21.14303
BALLISTIC RESEARCH LABORATORIES



ABERDEEN PROVING GROUND, MARYLAND

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A B E R D E E N P R O V I N G G R O U N D, M A R Y L A N D

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MEMORANDUM REPORT NO. 1362

HTLootens/bjk
Aberdeen Proving Ground, Md.
August 1961

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OBSERVED WITH THE DOPLOC SYSTEM

ABSTRACT

This report presents a series of constant frequency Doppler reflections obtained with the DOPLOC "dark" satellite tracking system. These reflections, termed "flats", are associated with satellite Doppler reflections and are of the type that would be received from a large, low velocity, ionized cloud. A tabulation of flats recorded at times other than satellite pass times is also given and a discussion of meteor-induced ionization is included.

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I. INTRODUCTION

During the period 1 January 1959 to 1 July 1960, the Ballistic Research Laboratories, under funding from the Advanced Research Projects Agency (ARPA Order 8-58), operated a three-station, reflection Doppler satellite tracking system, extending across the south-central United States from Tennessee to New Mexico. This system, known as DOPLLOC, (DOpple Phase LOCk), provided a means of detecting and tracking radio-silent, or "dark" satellites. Detailed reports outlining the planning, implementation, operation and administration of the DOPLLOC system have been published ^{1,2,3,4}, so no further space will be devoted to it here.

A transmitting station was located at Fort Sill, Oklahoma and receiving stations were located at White Sands Missile Range, New Mexico and at Forrest City, Arkansas. The three stations were initially manned on a twenty-four hour, seven-day-per-week basis, as a part of the nation-wide satellite surveillance net. Following permission from ARPA to discontinue routine twenty-four hour operation, the White Sands station was deactivated and a nominal eight-hour work day was adopted at the Forrest City and Fort Sill stations on 1 October 1959.

The primary objective of the DOPLLOC system was to detect and track non-transmitting (dark) satellites but the flexible schedule under which the field stations operated also provided considerable data from known satellites, Unidentified Flying Objects and meteors. In addition, the system provided much useful data relative to the satellite-induced ionization theory.

It is the purpose of this report to present data on this highly controversial subject of satellite-induced ionized trails or clouds. Several workers in the field, notably Kraus et al. at Ohio State University ^{5,6,7}, and Liszka et al. at the Kiruna Geophysical Observatory in Sweden ⁸, have reported the existence of satellite-induced ion trails. Many others in this field doubt the existence of such trails or are dubious about the reported magnitude and persistence of the trails.

This report will not attempt to confirm or refute the satellite-induced ionization theory, but rather will present reflection data acquired with the DOPLOC system which are of the type that would be obtained from a large, low velocity, ionized cloud. Reflections of the type presented in this report are definitely not from satellites, since satellite reflections are generally much shorter in duration and weaker in signal strength. Also the fact that these reflections occur as a constant Doppler frequency at the bias frequency level indicates that the reflecting mass has little or no velocity relative to the ground stations.

II. DOPLOC SYSTEM DESCRIPTION

The DOPLOC system consisted of a 50-kw continuous wave, 108 mc transmitter located at Fort Sill, Oklahoma, which fed one of three high-gain antennas. These high-gain antennas emitted narrow, fan-shaped beams, one directed 20 degrees above the northern horizon, one directed vertically and one directed 20 degrees above the southern horizon (see Figure 1).

The signal reflected from a satellite passing through the transmitter beam was received at one or both of the receiving stations. Each receiving station had three high-gain antennas oriented to "see" the space volume illuminated by the transmitter. The reflected signal was fed through a receiver and a bank of fixed audio frequency filters, known as the Automatic Lock-On (ALO), to a narrow-band, phase-locked tracking filter. The tracking filter then tracked the Doppler signal as the satellite passed through the antenna beam. A satellite which crossed the base line joining the transmitter and receiver traversed each of the three fan-shaped antenna beams. This resulted in three separate Doppler records, one for each of the three antennas, separated in time by 30-60 seconds. The length of the Doppler records varied, averaging about 7 seconds in the center antenna and 15-25 seconds in the north and south antennas. Data outputs were Doppler frequency as a function of time in a digital and punched tape format, as well as strip chart recordings of Doppler analog frequency and signal strength with respect to time. A complete and detailed description of the DOPLOC instrumentation system is available⁹, so no further discussion of it will be presented here.

When the DOPLOC system assumed twenty-four hour operational status in January 1959, the transmitter at Fort Sill served as the illuminator for both receiving stations. When the White Sands station was deactivated in the fall of 1959, the antennas at Fort Sill and Forrest City were re-oriented in azimuth to produce a greater overlapping of the beams and better coverage. All data presented in this report were recorded at the Forrest City station.

III. DATA FORMAT

A. Doppler Recording

The typical form in which DOPLOC data are recorded is shown in Figure 2. The upper portion of the chart is an analog record of tracking filter output frequency. The short, evenly spaced marks indicate the successive frequencies at which the tracking filter is set while the system is in the search mode. Figure 2 shows the tracking filter output when the ALO is scanning a 12 kc range. The ALO can also be adjusted to scan a 4 kc or 2 kc range.

The transition from step scanning to continuous phase-locked tracking is shown in Figure 2 at 1714:58 Z time. Concurrently, the digital counter and printer is started and the period of 1000 cycles of the Doppler signal is printed at one second intervals on paper tape. The Doppler period count for Revolution 183 of 59 Kappa, corresponding to the Doppler frequency analog record, is shown at the top left of Figure 2. The right five digits represent the period count, while the left six digits represent Universal Time in hours, minutes and seconds.

B. Signal Strength

The lower part of the chart in Figure 2 is a record of the AGC voltage from the tracking filter. While in the search mode, the AGC is shorted, producing the clean, straight line at 2 mm deflection. When a signal is detected, the AGC voltage first decreases due to an initial threshold voltage of opposite polarity existing on the AGC line. Then, as the signal amplitude increases, the AGC voltage increases as shown by the scale calibration. The chart is calibrated in received signal input power (in dbw) at the receiver input terminals and also in relative signal in terms of the signal-to-noise ratio at the receiver output, i.e. in db below 1:1 S/N at the receiver output.

C. Multiple Antenna Records

This one pass of 59 Kappa has been treated in considerable detail to explain the nature, quality and quantity of DOPLOC data and, consequently, the discussion has been devoted to data received by the vertically directed center antenna. In the next section of this report, examples of satellite passes recorded by more than one antenna will be presented.

During the 18-month operation of the DOPLOC system, 111 satellite reflections were received, resulting from observations of 89 individual satellite passes (8 passes were received by two antennas and 7 passes by all three antennas). Of these 111 reflections, 67 were received by the center antenna alone or by the center antenna in combination with the north or south antenna.

IV. EXPERIMENTAL RESULTS

A. "Flats" Associated with Satellite Passage

Approximately 25% of the satellite passes recorded by the DOPLOC center antenna (17 of 67) revealed a constant frequency reflection, either preceding or following the Doppler signal reflected from the satellite. These constant frequency reflections, termed "flats", appear on the analog records as a horizontal line, close to or equal to the bias frequency of 7 kc, indicating zero velocity. These Doppler frequency flats, which indicate an apparent zero velocity target, could be caused either by a large ionized mass moving through the antenna beam at a very low velocity, or by a stationary ionized mass having a lifetime equal to the duration of the observed signal. On 9 of the records the flats produced a stronger signal level than the corresponding satellite reflection. The average signal strength of the flats (-170 dbw) is slightly stronger than the average signal strength of the satellites observed (-171 dbw). Reproductions of DOPLOC satellite reflections showing evidence of flats are presented in Figures 3-19 and a tabulation of the data is given in Table I.

Of the 17 satellite records which reveal flats, 12 are reflections from 58 Delta 2 (Sputnik III). The other passes displaying flats are records of 59 Lambda (Discoverer VIII), 60 Epsilon 2 (Sputnik IV rocket) and 60 Epsilon 6 (Sputnik IV fragment). About 65% of the flats occur after (or before and after) the satellite has passed through the antenna beam, and all of the flats appear in the center antenna. Perhaps a brief explanation of the antenna switching procedure is desirable at this point, to indicate which antenna was in use when the flats were recorded.

In Figures 13, 14 and 17, an abrupt shift in the ALO frequency scan is visible. This shift represents the transfer of power from one antenna to the next. For example, in Figure 13, the ALO scans the 2-5 kc range as the satellite approaches and is tracked through the south antenna. Following loss of signal by the south antenna, power is switched to the center antenna and the ALO scans the 6-9 kc range. This transition is shown at 0641:46 Z time. This scan is continued until the satellite has traversed the center beam and then a switch is made to the north antenna

TABLE I - DOPLOC SATELLITE REFLECTIONS POSSESSING FLATS

Satellite	Rev.	Altitude Miles	Peak Signal Satellite	in dbw Flat	Flat Before/After Satellite Pass
58 Delta 2	8386	172	-167	-174	Before and After
58 Delta 2	8643	156	-170	-172	After
58 Delta 2	8683	413	-175	-165	Before
58 Delta 2	8719	186	-171	-172	After
58 Delta 2	9009	134	-175	-170	Before
58 Delta 2	9472	130	-172	-163	After
58 Delta 2	9503	130	-170	-175	After
58 Delta 2	9716	285	-176	-174	Before and After
58 Delta 2	9826	189	-176	-172	Before
58 Delta 2	9832	110	-171	-159	After
58 Delta 2	9937	158	-162	-168	Before and After
58 Delta 2	10001	124	-169	-175	Before
59 Lambda	96	124	-169	-174	Before
59 Lambda	1516	137	-167	-174	After
60 Epsilon 2	147	240	-175	-164	After
60 Epsilon 2	303	213	-175	-174	After
60 Epsilon 6	301	233	-175	-173	After
Average		184	-171	-170	

and a 10-13 kc scan range at 0643:12 Z time. The chart recorder pen deflection was adjusted at 0644:00 Z time and the satellite was subsequently tracked through the north antenna. This completes the antenna switching and recording cycle for this pass. Antenna switching was performed simultaneously at the transmitter and receiver and synchronized by teletype communication. In Figure 12, similar switching was performed as indicated at 1812:54 Z time, and the pen deflection subsequently adjusted to center the trace in the upper portion of the chart. It is probable that the flats observed in Figures 12, 13, and 17 would have been longer in duration if the recording had not been interrupted by antenna switching.

B. Flats During Random Periods

In an attempt to determine if a correlation actually exists between satellite passage and the occurrence of flats, it was decided to chart all of the flats and satellite passes which occurred during several arbitrarily selected periods between July 1959 and July 1960. The resulting charts are presented in Figures 20-25 and an explanation of them follows.

The original records were recorded on two-channel Sanborn chart paper, Type 651-52. During the operation of the DOPLOC system, over 300 complete rolls of this paper were utilized, amounting to more than 6000 hours of recordings. The six one-week periods chosen for this random examination are a representative sample of the total amount of data recorded. The first DOPLOC satellite reflection was received in August 1959, so the initial period to be studied was selected in July 1959, just prior to the first reflection. Five additional samples were chosen at approximately 1-2 month intervals, covering the time until the DOPLOC system was deactivated in July 1960. Each period examined consisted of five consecutive days, with the exception of the charts in Figures 22 and 24. The days that were omitted on these charts (19-20 Dec 59 and 2-3 Apr 60) fell on Saturday and Sunday, and the station was operating only on a five-day week at that time.

Each chart represents five complete days, and each day is divided into four segments of six hours each, with the horizontal scale reading from left to right in Universal Time. The short, vertical marks represent flats, with no regard for their duration. The flats vary in length from several seconds to a minute or more, but each one is represented by a single mark regardless of duration. A tabulation of all flats, including duration and signal strength values, is given in Tables II - VII.

The long, vertical marks represent satellites which were predicted for the DOPLOC system during the period. Each is identified with the year of launch and the Greek letter assigned by Space Track Control Center. In addition, the altitude of each pass as it crossed the base line is given. The periods labeled "NO DATA" represent periods when the station was not operating; at all other times the station was manned and continuous recordings were made. Several of the satellite passes are marked[†]. Here, the passage of the satellite through the antenna beam was recorded and reproductions of these Doppler frequency observations are presented in Figures 6, 13, 26-33.

Attention is called to the small number and random distribution of the flats in Figures 20 and 21. There is no correlation* with satellite passage in Figure 20 and only slight correlation in Figures 21, 24 and 25. In Figures 22 and 23, however, a number of excellent correlations are visible in connection with 58 Delta 2, perhaps because of the size and configuration of this satellite. Table VIII presents a summary of the number of passes in each period, together with the number of correlations and their identification.

In Figures 22-25, the occurrence frequency profile of the flats is radically different. Instead of a small number of flats randomly distributed, these charts show an increase in the number of flats by a factor of 3 or 4,

* Correlation denotes a minimum of two flats occurring in the period from 10 minutes before pass time until 20 minutes after pass time. These passes are underlined in Figures 20-25.

TABLE II

FLATS DURING PERIOD 22-26 JUL 59

DATE 1959	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1959	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1959	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1959	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw
22 JUL	0227:47	6	-159	23 JUL	1116:41	3	-159	24 JUL	0933:30	8	-165	26 JUL	0955:46	11	-159
	0315:13	5	-159		1117:29	7	-159		1115:24	8	-159		0958:09	5	-159
	0322:31	13	-159		1132:33	2	-159		1213:01	3	-171		0959:11	8	-159
	0342:07	3	-159		1139:12	15	-159		1213:46	2	-174		1059:08	5	-161
	0519:18	3	-159		1149:13	2	-159		1251:07	3	-164		1117:07	4	-160
	0551:16	13	-159		1236:39	2	-159		1305:22	3	-172		1118:56	4	-161
	0854:43	5	-159		1236:45	6	-159		1320:40	37	-159		1124:52	3	-174
	1042:21	4	-159		1353:37	23	-159		1418:53	5	-159		1127:02	6	-164
	1128:20	5	-159		1422:20	13	-159		1452:45	5	-159		1135:17	6	-163
	1131:45	4	-159		1426:34	2	-159		(NO DATA 1500-2400)				1308:29	14	-159
	1152:10	5	-159		1440:06	6	-159						1319:24	11	-159
	(NO DATA 1200-2400)				1442:10	17	-159	25 JUL	(NO FLATS FOR 25 JUL)				1335:20	6	-159
					1508:26	7	-159						1335:35	14	-159
23 JUL	0439:23	4	-159		1539:34	3	-159	26 JUL	0519:01	4	-159		1440:46	9	-159
	0707:24	3	-159		1556:28	2	-159		0519:14	6	-161		2251:21	2	-161
	0729:28	1	-159		(NO DATA 1600-2400)				0823:14	3	-159				
	0803:27	3	-159						0827:15	10	-159				
	0827:55	2	-159	24 JUL	0211:55	5	-159		0834:39	10	-159				
	0842:10	2	-159		0232:18	2	-171		0844:28	6	-159				
	1018:47	6	-159		0243:45	48	-165		0847:08	12	-159				
	1037:56	2	-159		0356:08	3	-159		0856:50	13	-159				
	1047:00	5	-159		0618:41	3	-165		0859:31	6	-159				
	1101:32	7	-159		0744:08	4	-161		0905:30	17	-159				
	1107:27	2	-159		0911:35	4	-159		0950:47	5	-159				

TABLE III

FLATS DURING PERIOD 13-17 SEP 59

DATE 1959	TIME U.T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1959	TIME U.T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1959	TIME U.T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1959	TIME U.T.	DURATION SECS.	PEAK SIGNAL dbw	
13 SEP	0006:19	9	-165	14 SEP	0043:07	2	-167	14 SEP	2108:27	2	-174	16 SEP	1601:55	4	-159	
	0007:14	3	-159		0107:05	80	-167		2235:05	7	-177		1722:37	6	-168	
	0320:39	3	-159		0110:08	3	-167		2245:05	2	-165		1728:40	11	-168	
	0402:20	7	-159		0133:06	63	-167						1813:01	3	-165	
	0555:38	7	-165		0135:01	135	-165		15 SEP (NO DATA 0000-1500)				1815:12	2	-159	
	0924:29	147	-171		0141:05	4	-171		1542:02	8	-167		1843:26	5	-159	
	1119:26	5	-159		0222:07	4	-171		1542:14	6	-171		1942:38	2	-177	
	1158:33	5	-159		1047:58	43	-165		1542:40	18	-171		2122:43	2	-162	
	1206:45	6	-159		1114:56	23	-174		1930:08	4	-169		2127:51	15	-159	
	1215:31	3	-159		1123:32	22	-165		1941:02	6	-167		2136:53	13	-159	
	1225:53	8	-183		1124:33	60	-162		1943:04	4	-167		2239:54	3	-167	
	1226:18	2	-165		1225:03	2	-177		1950:04	6	-167		2239:59	2	-168	
	1649:08	21	-159		1318:48	17	-174		2022:01	4	-177					
	1717:09	14	-159		1805:04	4	-159		2046:02	13	-159	17 SEP	0335:40	10	-168	
	1845:00	2	-159		1809:56	3	-159		2046:28	5	-167		0926:57	81	-162	
	2058:04	2	-167		1820:36	20	-168						0936:59	2	-171	
	2113:01	22	-171		1835:25	43	-159	16 SEP	0056:03	4	-167		1011:44	31	-159	
	2129:08	27	-171		1851:55	6	-159		0057:02	34	-171		1126:51	24	-177	
	2200:02	65	-171		1855:19	5	-159		0341:02	9	-167		1153:37	4	-159	
	2221:00	34	-171		1937:22	4	-180		0556:06	28	-159		1356:22	16	-168	
	2226:04	9	-171		1944:33	9	-159		0651:33	15	-159		1419:00	10	-159	
	2328:02	77	-171		2014:17	3	-183		0653:57	2	-159		1430:02	4	-165	
	2339:00	120	-171		2021:47	2	-180		1150:52	3	-159		1431:12	10	-171	

TABLE III (cont'd)

FLATS DURING PERIOD 13-17 SEP 59

TABLE IV

FLATS DURING PERIOD 15-21 DEC 59

DATE 1959	TIME U.T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1959	TIME U.T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1959	TIME U.T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1959	TIME U.T.	DURATION SECS.	PEAK SIGNAL dbw
15 DEC	0038:39	30	-167	15 DEC	1407:29	26	-165	15 DEC	1759:26	11	-165	16 DEC	0023:06	7	-171
	0115:22	59	-165		1412:12	11	-159		1759:46	6	-169		0023:21	2	-169
	0137:24	15	-159		1418:23	8	-165		1947:47	64	-159		0023:48	21	-165
	0144:03	27	-159		1420:46	9	-159		1957:04	23	-161		0024:28	26	-167
	0147:05	8	-159		1422:58	5	-159		2006:48	19	-159		0025:11	16	-169
	0234:22	14	-175		1425:58	4	-159		2102:11	18	-167		0025:47	10	-169
	0234:46	23	-169		1722:29	3	-169		2109:40	7	-169		0026:10	28	-165
	0235:37	14	-169		1723:28	5	-167		2118:32	9	-163		0027:04	8	-171
	0236:53	12	-169		1725:00	53	-165		2133:05	6	-165		0027:57	6	-171
	0237:20	38	-171		1734:23	2	-159		2137:53	3	-175		0030:15	17	-169
	0238:10	9	-177		1743:00	1	-159		2141:14	13	-159		0031:06	47	-159
	0238:32	7	-165		1743:31	32	-165		2333:53	7	-159		0035:32	6	-159
	0250:11	24	-159		1746:16	4	-171						0035:55	10	-169
	0258:40	2	-171		1747:20	9	-167	16 DEC	0014:36	12	-159		0037:00	24	-165
	0259:32	6	-159		1749:23	9	-167		0015:37	8	-161		0042:05	10	-167
	0309:02	2	-171		1751:18	7	-171		0016:08	3	-171		0043:51	5	-169
	0327:32	3	-161		1753:19	14	-161		0016:23	6	-171		0044:04	18	-165
	0335:04	4	-165		1753:46	5	-169		0016:39	19	-161		0101:45	8	-177
	0343:25	5	-159		1754:10	2	-171		0017:16	2	-177		0109:12	80	-167
	(NO DATA 0400-1300)				1754:36	3	-165		0018:04	7	-169		0127:02	37	-167
	1354:25	"	-165		1754:47	9	-165		0019:53	13	-171		0212:47	40	-165
	1356:26	1	-167		1756:48	8	-165		0020:13	9	-171		0213:41	80	-165
	1357:05	14	-165		1757:34	23	-165		0020:35	9	-171		0215:09	25	-169
	1400:50	15	-159		1758:28	4	-171		0020:54	3	-167		0215:39	25	-167

TABLE IV (cont'd)

FLATS DURING PERIOD 15-21 DEC 1959

DATE 1959	TIME U.T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1959	TIME U.T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1959	TIME U.T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1959	TIME U.T.	DURATION SECS.	PEAK SIGNAL dbw
16 DEC	0216:15	58	-165	16 DEC	1343:18	13	-159	16 DEC	1537:00	25	-159	16 DEC	1733:05	28	-159
	0217:41	8	-161		1343:37	28	-165		1537:59	15	-169		1737:55	11	-169
	0217:58	32	-165	1344:33	20	-161		1538:25	6	-161		1739:39	4	-175	
	0218:00	10	-165	1346:32	7	-167		1542:48	20	-165		1746:15	77	-163	
	0326:44	6	-175	1346:45	2	-169		1545:43	80	-159		1750:47	10	-165	
	0327:34	18	-165	1351:37	14	-165		1549:27	34	-165		1819:23	14	-159	
	0328:15	40	-161	1403:32	21	-163		1552:24	40	-161		1841:17	7	-159	
	0329:15	34	-165	1442:03	16	-161		1630:44	24	-165		1843:32	140	-161	
	0331:31	13	-165	1442:22	47	-159		1633:30	80	-165		1901:38	158	-165	
	0333:35	65	-165	1450:33	3	-159		1635:21	24	-159		1910:34	9	-159	
	0335:50	66	-165	1451:30	10	-163		1638:25	11	-159		1911:31	9	-165	
	0420:53	298	-159	1456:42	5	-171		1643:55	5	-159		1914:45	6	-159	
	0426:51	15	-167	1500:19	2	-169		1648:23	58	-159		1916:58	6	-159	
	0431:22	40	-165	1500:50	60	-165		1652:53	30	-165		1928:38	32	-167	
	0434:21	24	-167	1503:05	14	-165		1653:55	69	-163		1929:48	59	-165	
	0436:35	10	-171	1505:10	35	-159		1657:00	52	-165		1932:48	31	-165	
	0442:01	42	-165	1508:55	12	-159		1702:21	80	-165		1936:47	13	-169	
	0451:38	5	-161	1509:23	6	-165		1703:52	63	-165		1940:25	5	-159	
	0452:11	175	-165	1513:43	14	-165		1705:07	28	-159		2015:13	9	-159	
(NO DATA 0500-1300)				1514:11	13	-165		1710:54	14	-159		2030:08	19	-165	
	1339:02	3	-169	1514:26	12	-167		1717:56	20	-159		2031:31	31	-165	
	1340:50	22	-159	1521:44	23	-165		1718:23	25	-165		2036:29	8	-165	
	1341:03	22	-165	1526:40	7	-167		1722:40	22	-165		2039:50	12	-159	
	1342:56	5	-161	1535:55	20	-159		1728:43	14	-167		2110:46	9	-159	

TABLE IV (cont'd)

FLATS DURING PERIOD 15-21 DEC 59

DATE 1959	TIME U.T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1959	TIME U.T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1959	TIME U.T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1959	TIME U.T.	DURATION SECS.	PEAK SIGNAL dbw
16 DEC	2136:10	10	-159	17 DEC	0045:02	5	-171	17 DEC	0230:10	55	-165	17 DEC	1320:44	32	-159
	2140:47	40	-165		0102:51	20	-167		0238:22	80	-163		1322:08	19	-165
	2228:08	44	-165		0107:25	5	-171		0240:36	38	-169		1326:26	10	-171
	2230:39	59	-169		0110:11	28	-169		0242:13	31	-165		1327:44	14	-159
	2232:55	38	-165		0123:50	11	-171		0243:13	36	-165		1328:50	14	-165
	2237:55	67	-167		0128:40	37	-165		0245:25	58	-165		1330:05	9	-159
	2240:19	108	-159		0129:54	10	-171		0248:09	35	-167		1331:04	6	-167
	2251:49	264	-165		0134:45	9	-171		0250:14	10	-167		1332:45	12	-167
					0135:37	3	-175		0250:52	21	-167		1333:57	8	-165
23	17 DEC	0016:06	11	-167	0136:08	10	-165		0252:00	24	-167		1335:16	7	-169
	0017:12	24	-165		0136:57	8	-171		0253:40	4	-171		1339:06	12	-159
	0018:03	20	-169		0138:09	13	-165		0257:47	22	-169		1342:44	24	-165
	0020:02	54	-165		0138:58	63	-165		0300:39	20	-167		1348:53	22	-165
	0021:17	11	-171		0140:54	11	-165		0312:55	3	-177		1412:09	7	-169
	0023:06	2	-175		0215:00	11	-167		0313:05	8	-169		1414:52	44	-165
	0024:50	22	-165		0215:51	29	-163		0314:55	29	-167		1415:44	21	-165
	0025:34	12	-171		0216:47	2	-171		0316:53	15	-169		1416:54	26	-165
	0026:52	24	-167		0217:05	18	-159		0334:06	40	-167		1417:29	68	-165
	0027:59	18	-169		0218:05	8	-169		0337:37	48	-165		1418:45	10	-165
	0029:18	8	-171		0220:33	12	-167		0344:22	16	-169		1419:05	51	-165
	0031:32	8	-171		0221:05	54	-159		0347:12	25	-169		1420:20	18	-165
	0036:16	6	-165		0222:28	8	-169		(NO DATA 0400-1300)				1425:51	29	-165
	0042:00	6	-177		0224:07	18	-165		1315:20	9	-171		1427:25	4	-175
	0044:11	3	-177		0226:53	53	-159		1318:26	12	-171		1428:35	65	-165

TABLE IV (cont'd)

FLATS DURING PERIOD 15-21 DEC 59

DATE 1959	TIME U.T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1959	TIME U.T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1959	TIME U.T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1959	TIME U.T.	DURATION SECS.	PEAK SIGNAL dbw
17 DEC	1430:00	8	-165	17 DEC	1723:56	19	-171	17 DEC	2344:14	2	-177	18 DEC	0334:48	35	-177
	1430:21	59	-165		1811:31	3	-171						0336:00	30	-174
	1433:09	9	-165		1823:27	66	-171		0012:51	6	-171		0340:42	19	-177
	1438:34	74	-165		1836:24	25	-168		0037:09	7	-177		0342:32	80	-171
	1440:00	86	-165		1836:52	88	-177		0121:38	3	-174		0413:52	12	-174
	1441:54	26	-165		1855:07	14	-174		0121:55	3	-177		0425:19	16	-174
	1443:43	65	-165		1903:19	6	-159		0122:43	40	-174		0445:51	48	-171
	1446:09	23	-169		2012:32	3	-177		0123:43	34	-168		0447:20	75	-171
	1447:18	62	-165		2141:45	31	-177		0129:23	10	-174		0449:31	55	-168
	1449:32	9	-159		2056:42	37	-171		0129:40	25	-171		0451:21	18	-174
	1453:52	15	-159		2111:08	20	-171		0137:00	35	-177	(NO DATA 0500-1300)			
	1500:42	21	-159		2138:53	2	-159		0210:42	8	-174	1301:24	1	-159	
	1501:47	48	-165		2211:31	6	-174		0231:16	6	-174	1301:38	3	-171	
	1507:55	21	-165		2242:36	49	-171		0316:47	20	-174	1314:16	7	-171	
	1509:27	41	-169		2248:24	45	-177		0317:32	10	-177	1318:59	5	-177	
	1511:02	11	-169		2255:20	3	-177		0319:33	25	-171	1517:39	27	-171	
	1515:18	4	-159		2302:30	3	-159		0320:21	29	-174	1530:07	43	-165	
	1520:28	2	-159		2310:20	43	-177		0321:28	53	-174	1533:36	5	-171	
	1526:46	29	-165		2317:21	18	-174		0322:57	2	-177	1534:44	32	-171	
	1533:34	17	-159		2317:58	2	-165		0323:34	28	-177	1538:16	5	-171	
	1534:27	20	-159		2318:00	60	-174		0326:50	35	-171	1538:54	42	-171	
	1550:22	12	-159		2337:58	9	-177		0329:53	13	-177	1540:03	15	-171	
	1644:48	32	-174		2340:39	12	-174		0330:56	62	-174	1546:04	9	-174	
	1655:55	144	-165		2343:19	13	-171		0331:17	11	-177	1635:00	51	-168	

TABLE IV (cont'd)

FLATS DURING PERIOD 15-21 DEC 59

TABLE V

FLATS DURING PERIOD 12-16 JAN 60

DATE 1960	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1960	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1960	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1960	TIME U. T.	DURATION SECS	PEAK SIGNAL dbw
12 JAN	0022:18	18	-171	12 JAN	0214:03	2	-179	12 JAN	0341:39	28	-174	12 JAN	0518:55	19	-174
	0023:00	22	-171		0217:40	2	-161		0413:23	23	-175		0521:56	10	-171
	0023:46	40	-173		0226:20	18	-177		0414:33	61	-169		0531:50	16	-173
	0024:35	26	-173		0231:44	36	-174		0416:50	13	-174		0532:53	3	-161
	0028:15	12	-171		0233:24	15	-174		0417:21	83	-171		0537:00	30	-165
	0040:58	170	-169		0238:13	46	-171		0419:09	18	-171		0555:01	60	-167
	0044:25	14	-169		0241:00	2	-165		0434:25	27	-171		0601:00	40	-165
	0050:06	6	-174		0243:15	21	-174		0436:31	5	-177		0610:04	12	-167
	0052:13	38	-171		0249:37	6	-175		0437:09	16	-165		0616:38	4	-169
	0053:57	85	-167		0252:29	14	-177		0438:29	33	-169		0616:44	3	-169
	0056:12	9	-177		0256:08	5	-177		0440:50	16	-177		0618:02	6	-175
	0057:14	12	-173		0303:46	64	-171		0442:20	43	-165		0621:15	6	-169
	0059:10	27	-171		0306:20	12	-177		0444:07	59	-165		0623:28	8	-165
	0101:12	4	-177		0315:56	3	-161		0445:25	66	-169	(NO DATA 0700-1400)			
	0104:05	66	-169		0316:51	9	-177		0451:40	62	-165	1419:17	2	-169	
	0106:05	8	-167		0317:50	22	-171		0457:55	31	-159	1420:04	3	-165	
	0106:56	44	-169		0320:25	65	-171		0459:49	17	-175	1421:06	4	-177	
	0108:23	11	-169		0322:00	55	-171		0502:00	52	-174	1426:10	13	-169	
	0112:37	6	-177		0324:41	4	-177		0503:06	14	-179	1432:53	12	-169	
	0113:52	37	-169		0325:12	12	-171		0504:23	16	-179	1454:32	6	-171	
	0114:58	39	-167		0330:00	12	-174		0509:08	14	-171	1501:45	1	-161	
	0115:52	16	-167		0331:13	26	-173		0511:23	51	-171	1512:17	8	-169	
	0121:18	12	-168		0335:09	21	-177		0512:38	9	-171	1513:58	1	-174	
	0126:19	5	-179		0337:11	15	-171		0513:29	10	-173	1514:31	3	-173	
	0132:18	8	-159		0339:21	73	-169		0515:11	3	-177	1515:15	4	-164	

TABLE V (cont'd)

FLATS DURING PERIOD 12-16 JAN 60

DATE 1960	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1960	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1960	TIME U. T.	DURATION SECS	PEAK SIGNAL dbw	DATE 1960	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw
12 JAN	1523:57	4	-171	13 JAN	0317:46	13	-171	13 JAN	1417:18	19	-169	13 JAN	1506:42	15	-171
	1525:14	12	-171		0318:30	12	-171		1419:12	67	-165		1507:26	9	-171
	1530:27	3	-174		0320:01	10	-171		1421:41	24	-165		1507:52	11	-171
	1538:35	5	-171		0321:51	14	-171		1422:53	2	-161		1509:05	25	-171
	1612:28	4	-171		0323:27	6	-173		1425:20	1	-165		1511:52	36	-171
	1614:48	9	-171		0324:30	8	-171		1427:26	52	-171		1513:27	7	-171
	1628:43	3	-175		0326:00	1	-159		1428:51	15	-169		1513:38	6	-171
	1634:22	5	-171		0327:36	9	-173		1429:19	15	-165		1514:40	8	-171
	1732:09	3	-171		0328:04	22	-169		1431:23	19	-165		1515:26	4	-171
	1737:34	13	-177		0329:17	1	-163		1432:15	23	-171		1516:55	6	-171
	1803:03	4	-169		0330:17	10	-171		1433:42	10	-171		1517:13	3	-175
	1831:24	6	-177		0332:05	8	-173		1434:38	2	-171		1517:52	7	-169
	1847:00	10	-159		0339:43	11	-169		1435:50	11	-165		1518:06	4	-169
	(NO DATA 1900-2400)				0343:10	5	-169		1436:41	6	-175		1519:45	6	-174
					0344:13	12	-171		1439:30	29	-169		1520:11	3	-171
13 JAN	0025:37	1	-159		0345:39	8	-169		1441:54	9	-177		1521:25	4	-175
	0029:17	3	-159		0348:30	10	-171		1442:40	19	-175		1523:13	5	-167
	0029:35	3	-173		0350:11	27	-167		1443:43	44	-169		1524:20	8	-171
	0035:49	5	-171		0421:25	1	-162		1444:49	11	-174		1525:09	3	-171
	0037:42	1	-165		0434:36	21	-171		1445:27	9	-171		1525:16	4	-171
	0107:22	23	-165		(NO DATA 0500-1300)				1453:03	93	-171		1526:02	4	-174
	0111:39	13	-171		1340:32	14	-169		1456:09	2	-165		1526:40	4	-169
	0133:10	9	-165		1342:25	135	-169		1459:27	77	-171		1527:50	2	-167
	0217:58	22	-165		1346:49	65	-169		1502:56	16	-174		1711:30	160	-167
	0236:25	6	-171		1349:38	2	-161		1504:12	113	-171		1715:41	100	-165

TABLE V (cont'd)

FLATS DURING PERIOD 12-16 JAN 60

DATE 1960	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1960	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1960	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1960	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw
13 JAN	1718:01	32	-171	13 JAN	1849:46	2	-174	13 JAN	2044:36	4	-175	13 JAN	2137:22	10	-174
	1720:25	18	-171		1850:16	11	-175		2045:10	2	-162		2138:09	18	-171
	1729:29	25	-169		1850:37	8	-171		2046:55	8	-171		2143:43	22	-171
	1730:56	4	-175		1851:16	2	-175		2052:17	28	-171		2144:33	23	-174
	1731:59	6	-175		1857:16	22	-165		2053:54	3	-174		2226:00	100	-171
	1738:22	108	-169		1858:46	3	-171		2057:07	46	-175		2230:44	8	-175
	1740:37	68	-169		1859:06	15	-171		2100:02	2	-164		2232:34	7	-174
	1816:45	2	-177		1900:05	10	-175		2100:28	9	-177		2234:31	21	-171
	1817:03	6	-177		1907:31	65	-171		2101:11	4	-174				
	1818:20	54	-169		1909:37	5	-175		2101:45	1	-165	14 JAN	0011:18	57	-169
	1820:31	16	-177		1912:19	15	-171		2103:07	11	-171		0022:32	59	-169
	1825:16	98	-171		1913:15	2	-177		2104:36	18	-173		0029:17	76	-171
28	1827:34	11	-171		1914:00	4	-171		2107:51	14	-171		0057:08	45	-169
	1828:56	8	-173		1915:26	2	-161		2109:09	4	-159		0113:35	38	-169
	1830:37	31	-169		1919:14	14	-173		2110:23	12	-173		0127:41	29	-171
	1832:09	63	-171		1921:24	20	-171		2116:29	8	-174		0131:32	7	-174
	1833:25	37	-171		1925:10	25	-171		2118:31	22	-171		0133:29	14	-174
	1835:08	13	-169		1926:50	22	-171		2122:54	20	-169				(NO DATA 0200-1400)
	1837:20	19	-171		1927:30	2	-175		2123:52	30	-171		1437:14	5	-171
	1838:37	1	-167		1929:59	14	-171		2124:28	24	-169		1440:36	3	-161
	1840:17	4	-177		1931:21	32	-171		2126:00	15	-171		1444:55	5	-171
	1841:43	14	-174		2030:22	3	-177		2130:05	15	-173		1449:30	3	-175
	1843:45	6	-159		2034:01	35	-171		2130:44	23	-171		1519:13	8	-174
	1844:17	7	-167		2037:24	25	-169		2132:49	42	-174		1525:05	26	-171
	1847:27	7	-173		2041:05	18	-171		2134:59	12	-174		1527:37	8	-173
	1849:07	16	-171		2042:32	37	-171		2135:52	5	-162		1528:37	4	-173

TABLE V (cont'd)

FLATS DURING PERIOD 12-16 JAN 60

DATE 1960	TIME U. T.	DURATION SECS	PEAK SIGNAL dbw	DATE 1960	TIME U. T.	DURATION SECS	PEAK SIGNAL dbw	DATE 1960	TIME U. T.	DURATION SECS	PEAK SIGNAL dbw	DATE 1960	TIME U. T.	DURATION SECS	PEAK SIGNAL dbw
14 JAN	1533:06	1	-163	14 JAN	1652:37	53	-171	14 JAN	1732:47	18	-174	14 JAN	1945:46	14	-175
	1535:35	6	-173		1653:40	10	-174		1733:38	15	-174		1947:23	14	-174
	1538:02	22	-171		1655:50	4	-173		1734:37	9	-174		1953:47	7	-173
	1541:12	9	-175		1656:10	12	-171		1735:51	1	-177		1954:01	33	-161
	1542:08	32	-171		1656:51	7	-173		1736:50	1	-175		1957:14	15	-175
	1542:49	4	-174		1657:17	5	-173		1738:02	4	-175		1959:58	1	-173
	1543:06	7	-171		1658:31	52	-165		1739:28	12	-173		2015:50	15	-175
	1544:26	4	-177		1700:35	17	-171		1740:03	6	-173		2018:22	16	-174
	1611:00	7	-175		1701:34	9	-159		1741:00	10	-175		2033:35	17	-174
	1613:29	8	-173		1702:45	6	-165		1744:48	2	-171		2042:06	25	-159
	1615:28	3	-159		1705:18	6	-174		1746:02	4	-175		2105:28	7	-177
	1616:27	17	-171		1706:53	1	-173		1750:18	9	-173		2115:46	3	-177
	1620:16	3	-171		1707:14	6	-177		1909:51	2	-171		2124:26	9	-174
	1622:30	6	-174		1709:26	9	-175		1912:52	2	-177		2128:56	8	-174
	1624:41	32	-171		1710:12	17	-173		1915:22	12	-171		2129:30	21	-174
	1628:14	2	-173		1711:46	1	-177		1917:01	2	-162		2131:27	2	-177
	1633:32	1	-177		1712:10	4	-175		1919:52	17	-174		2132:23	59	-171
	1635:01	9	-171		1718:17	26	-173		1925:39	7	-173		2210:44	4	-177
	1636:38	14	-174		1719:18	6	-177		1930:21	9	-171		2215:19	1	-177
	1637:49	25	-171		1720:25	16	-171		1931:23	10	-171		2300:36	4	-177
	1639:40	11	-175		1722:03	14	-173		1934:07	6	-177		2302:49	2	-165
	1641:49	73	-173		1723:39	11	-171		1938:18	4	-177		2303:12	13	-177
	1644:40	13	-171		1724:10	20	-171		1939:18	3	-177		2305:43	6	-177
	1650:10	49	-171		1726:04	7	-165		1940:28	11	-165		2332:02	30	-175
	1651:32	4	-175		1728:43	9	-165		1941:12	6	-173		2339:51	2	-177

TABLE V (cont'd)

FLATS DURING PERIOD 12-16 JAN 60

DATE 1960	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1960	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1960	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1960	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw	
15 JAN	0017:50	26	-159	15 JAN	0258:04	7	-175	15 JAN	2127:47	42	-171	16 JAN	0038:49	190	-171	
	0018:39	16	-170		0301:58	260	-165		2130:47	14	-174		0044:52	3	-161	
	0019:12	12	-168		0310:46	2	-177		2131:16	19	-174		0049:32	24	-171	
	0025:37	55	-171		0315:10	5	-170		2133:06	25	-175		0051:16	29	-173	
	0026:42	15	-159		0317:12	12	-174		2135:01	51	-171		0057:20	63	-171	
	0027:18	2	-177		0320:10	20	-171		2139:51	58	-171		0105:32	18	-171	
	0028:13	26	-171		0321:09	23	-169		2142:37	5	-177		0106:32	15	-174	
	0029:33	80	-170		0328:08	20	-171		2147:28	9	-177		0107:35	1	-179	
	0031:29	32	-171		0332:42	12	-169		2148:49	19	-174		0108:20	12	-174	
	0033:29	16	-171		0435:30	5	-159		2257:50	102	-171		0115:26	41	-169	
	0034:12	8	-171	(NO DATA 0500-1400)					2313:31	42	-171		0117:28	39	-171	
	0037:32	3	-177	1413:07	16	-171	2323:09		38	-174	0120:43		1	-159		
	0037:44	33	-170	1423:10	62	-171	2324:45		19	-174	0121:25		15	-171		
	0039:52	17	-171	1424:53	31	-171	2331:31		152	-171	0138:30		20	-167		
	0043:46	9	-171	1430:30	9	-159	2335:42		37	-171	0140:26		108	-171		
	0101:10	3	-177	1431:59	9	-174	2338:22		83	-171	0146:12		49	-174		
	0101:30	41	-169	1432:33	275	-167	2343:06		20	-174	0212:40		31	-171		
	0109:15	2	-167	1613:42	130	-169	2346:06		63	-171	0215:00		12	-179		
	0110:07	4	-177	1616:48	15	-171					0216:23		124	-165		
	0121:31	7	-177	2106:44	250	-171	16 JAN	0012:00	10	-171	0221:40		51	-171		
	0134:55	150	-165	2113:35	4	-177		0014:28	85	-165	0224:33		30	-174		
	0217:04	270	-159	2114:01	18	-171		0022:07	39	-169	0232:29		15	-171		
	0233:08	7	-171	2115:32	8	-177		0029:21	12	-161	0238:39		2	-177		
	0252:38	7	-171	2120:47	110	-171		0037:19	7	-174	0241:21		350	-165		
	0257:41	16	-171	2126:35	46	-171		0037:54	23	-159	0248:36		67	-171		

TABLE V (cont'd)

FLATS DURING PERIOD 12-16 JAN 60

TABLE VI

FLATS DURING PERIOD 31 MAR - 6 APR 60

DATE 1960	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1960	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1960	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1960	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw
31 MAR	(NO DATA 0000-0600)			31 MAR	1507:45	12	-175	31 MAR	2005:25	8	-166	31 MAR	2125:32	9	-175
	1343:04	15	-171		1512:21	9	-175		2005:57	8	-171		2126:14	35	-169
	1344:37	18	-171		1513:40	12	-177		2007:29	3	-159		2128:31	4	-177
	1345:56	8	-177		1840:03	5	-165		2008:00	9	-168		2129:27	12	-177
	1356:43	73	-168		1840:30	8	-165		2008:15	4	-177		2129:59	43	-167
	1401:00	6	-172		1844:28	12	-168		2011:04	9	-170		2132:02	54	-167
	1402:32	11	-172		1844:48	12	-165		2016:35	19	-169		2135:01	19	-170
	1402:54	15	-167		1846:18	38	-169		2018:40	9	-175		2136:08	7	-175
	1403:15	14	-167		1847:09	65	-165		2039:45	13	-159		2137:17	20	-167
	1406:17	10	-173		1848:32	22	-171		2055:23	8	-174		2139:28	5	-169
	1407:15	5	-173		1852:39	60	-171		2055:38	6	-169		2147:27	3	-179
	1412:08	10	-167		1905:40	56	-167		2056:15	5	-167		2148:10	20	-169
	1413:27	17	-173		1917:12	45	-165		2056:28	4	-171		2149:53	4	-170
	1420:21	8	-170		1924:56	31	-166		2102:11	6	-171		2159:00	15	-169
	1428:41	13	-171		1926:25	8	-177		2102:51	5	-167				
	1436:52	9	-168		1927:52	84	-169		2105:52	11	-168	1 APR	(NO DATA 0000-1100)		
	1437:55	19	-165		1930:20	24	-166		2106:28	5	-165		1144:20	18	-171
	1444:19	5	-177		1930:53	6	-167		2109:22	7	-179		1351:44	19	-173
	1450:30	17	-175		1931:18	5	-169		2113:05	5	-179		1352:52	5	-177
	1451:17	19	-170		1935:32	31	-167		2113:34	3	-171		1353:11	7	-175
	1452:06	10	-168		1940:52	11	-173		2115:09	7	-173		1355:44	3	-169
	1455:31	6	-173		1941:30	20	-173		2117:16	10	-173		1356:57	6	-172
	1459:42	17	-168		1946:53	29	-169		2121:46	10	-171		1357:27	11	-175
	1504:12	8	-168		1952:56	69	-166		2123:21	18	-171		1359:30	19	-169
	1505:07	31	-171		1956:20	20	-170		2124:05	22	-171		1405:25	5	-175

TABLE VI (cont'd)

FLATS DURING PERIOD 31 MAR - 6 APR 60

DATE 1960	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1960	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1960	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1960	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw
1 APR	1406:57	26	-165	1 APR	1753:19	23	-173	4 APR	1927:03	24	-162	4 APR	2200:54	47	-175
	1417:15	14	-168		1753:55	12	-175		1928:04	18	-161		2202:00	64	-167
	1430:13	6	-175		1754:17	109	-163		1929:00	14	-161		2203:15	46	-167
	1434:22	10	-177		1756:36	23	-169		1930:28	12	-173		2205:25	10	-177
	1435:10	7	-178		1757:47	3	-179		1934:45	6	-168		2205:50	8	-177
	1439:52	13	-171		1758:18	15	-175		1936:20	14	-173		2208:13	6	-163
	1444:15	17	-168		1758:58	14	-166		1937:00	7	-168		2209:00	8	-179
	1446:40	18	-160		1759:51	3	-179		2031:30	5	-163		2210:49	8	-177
	1448:18	69	-165		1800:03	4	-167		2032:00	7	-159		2212:06	7	-175
	1450:15	60	-167		1800:30	22	-169		2037:13	114	-167		2213:37	10	-174
	1452:37	7	-169		1806:14	8	-173		2039:46	20	-167		2214:25	4	-179
	1456:18	18	-171		1807:48	25	-170		2044:20	19	-169		2215:31	19	-169
	1458:08	16	-169		1813:51	8	-171		2048:31	25	-163		2216:00	7	-161
	1731:00	9	-175		1816:45	4	-177		2050:20	15	-167		2216:15	4	-169
	1732:32	10	-177		1816:53	9	-171		2054:17	12	-171		2217:44	18	-169
	1734:04	14	-174		1831:11	9	-177		2056:35	23	-169		2218:20	5	-175
	1734:50	5	-168		1837:44	28	-167		2100:21	48	-167		2219:06	5	-173
	1735:06	8	-177		1840:05	14	-166		2104:56	8	-169		2221:12	5	-159
	1735:21	11	-176		1858:02	12	-166		2105:27	9	-175		2225:31	20	-171
	1739:12	5	-172						2108:52	5	-161		2226:00	5	-169
	1740:59	9	-173	4 APR	(NO DATA 0000-1400)				2109:34	6	-171		2227:27	32	-171
	1744:06	56	-164		1446:09	2	-162		2110:27	8	-175		2229:08	13	-171
	1745:40	15	-165		1447:03	4	-170		2117:28	5	-167		2230:56	7	-174
	1746:04	33	-164		1447:32	3	-175		2154:31	6	-173		2235:50	6	-165
	1750:10	4	-177		1926:23	8	-164		2155:00	12	-167		2241:19	8	-173
	1750:27	29	-169		1926:37	8	-167		2157:55	8	-177		2242:16	10	-173

TABLE VI (cont'd)

FIATS DURING PERIOD 31 MAR - 6 APR 60

DATE 1960	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1960	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1960	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1960	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw
4 APR	2248:24	9	-171	5 APR	0053:36	167	-171	5 APR	1543:17	5	-172	5 APR	1914:49	13	-175
	2250:14	7	-169		0059:21	35	-169		1544:10	8	-173		1916:59	7	-169
	2252:32	8	-174		0109:53	101	-171		1549:29	18	-171		1918:35	15	-173
	2252:52	11	-173		0112:03	32	-169		1552:00	5	-173		1919:13	9	-171
	2253:18	10	-171	(NO DATA 0200-1000)					1554:23	10	-174		1919:35	19	-169
	2255:37	9	-173		1124:35	17	-171		1605:34	9	-159		1920:15	7	-170
	2256:04	14	-171		1126:11	5	-169		1608:53	8	-171		1923:58	6	-166
	2317:38	8	-159		1128:44	5	-161		1614:01	6	-174		1924:20	8	-173
	2319:00	5	-177		1130:44	5	-173		1615:11	13	-173		1927:05	46	-166
	2327:14	138	-163		1131:18	3	-177		1620:29	6	-173		1932:23	29	-175
	2333:26	8	-171		1132:12	4	-171		1622:33	11	-174		1934:57	12	-172
	2336:18	59	-174		1133:05	5	-167		1629:21	38	-174		1936:43	12	-175
	2337:51	35	-171		1134:06	3	-167		1638:05	10	-175		1938:36	180	-173
	2342:45	110	-168		1136:19	5	-159		1643:16	16	-175		1948:21	8	-171
	2347:10	8	-171		1137:00	8	-159		1648:12	9	-175		1951:00	30	-175
					1138:46	7	-159		1839:28	5	-176		1952:22	15	-177
5 APR	0014:06	16	-165		1140:11	3	-169		1841:08	3	-177		1954:26	10	-177
	0017:18	9	-167		1143:00	3	-175		1842:18	3	-173		1955:31	32	-171
	0017:36	13	-165		1144:42	4	-169		1843:46	7	-166		1956:38	11	-162
	0021:18	8	-172		1418:25	4	-171		1844:02	7	-169		2000:30	12	-172
	0025:31	14	-171		1527:25	5	-173		1844:15	3	-169		2014:44	25	-171
	0026:03	10	-164		1531:55	13	-174		1844:49	4	-175		2016:25	16	-171
	0034:19	221	-159		1536:15	7	-173		1912:13	5	-177		2017:15	134	-159
	0039:50	15	-161		1537:03	11	-174		1913:47	13	-169		2020:05	92	-169
	0046:36	165	-159		1541:20	19	-174		1914:20	8	-175		2021:46	23	-175

TABLE VI (cont'd)

FLATS DURING PERIOD 31 MAR - 6 APR 60

DATE 1960	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1960	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1960	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1960	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw
5 APR	2022:15	149	-173	5 APR	2148:16	36	-174	6 APR	0110:14	12	-173	6 APR	1343:41	5	-177
	2027:26	34	-171		2152:08	21	-175		0112:05	10	-173		1344:27	6	-175
	2031:00	23	-159		2153:18	12	-173		0124:10	9	-162		1346:30	24	-177
	2032:08	19	-169		2210:07	22	-175		0125:32	8	-177		1348:40	11	-173
	2032:47	25	-173		2210:33	7	-160		0150:52	12	-169		1350:39	7	-173
	2037:50	10	-169		2212:31	13	-165		0216:00	30	-173		1352:51	9	-179
	2044:01	241	-172		2218:27	12	-171		0217:02	29	-171		1400:40	20	-177
	2049:55	8	-161		2228:25	12	-172		0219:12	9	-175		1403:13	18	-175
	2051:27	10	-175		2228:52	9	-177		0221:58	8	-166		1405:47	38	-177
	2054:05	99	-171		2229:36	17	-167		0222:40	32	-169		1417:43	21	-177
	2059:45	27	-171		2232:43	32	-169		0224:52	19	-169		1709:20	5	-165
	2101:08	23	-175		2240:26	17	-174		0227:07	25	-169		1710:53	6	-173
	2102:56	20	-175		2241:21	12	-175		0229:24	24	-165		1711:52	31	-171
	2106:20	10	-171		2241:40	11	-173		0231:14	16	-169		1712:40	18	-169
	2107:58	32	-172		2242:49	17	-171		0236:41	17	-172		1714:02	59	-169
	2110:15	14	-177		2250:16	12	-175		0239:03	8	-175		1716:52	21	-169
	2111:26	7	-177		2250:55	15	-165		0243:18	33	-167		1731:05	40	-169
	2112:45	13	-177		2334:30	8	-169		0244:21	17	-170		1736:35	127	-167
	2113:41	14	-169						0245:04	69	-170		1756:37	7	-165
	2116:35	5	-173	6 APR	0054:33	21	-177		0257:30	36	-169		1806:04	13	-174
	2117:41	26	-159		0100:32	5	-166		0304:36	14	-172		1828:31	15	-172
	2119:37	14	-168		0103:17	14	-173		0315:40	15	-175		1832:13	22	-170
	2132:30	37	-171		0105:57	34	-173				(NO DATA 0400-1300)		1837:05	138	-159
	2137:53	14	-171		0106:50	16	-177		1338:26	7	-165		1842:36	96	-174
	2145:41	9	-171		0108:26	11	-177		1342:15	5	-173		1849:54	8	-165

TABLE VI (cont'd)

FLATS DURING PERIOD 31 MAR - 6 APR 60

TABLE VII

FLATS DURING PERIOD 6-10 JUN 60

DATE 1960	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1960	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1960	TIME U. T.	DURATION SECS	PEAK SIGNAL dbw	DATE 1960	TIME U. T.	DURATION SECS	PEAK SIGNAL dbw
6 JUN	(NO DATA 0000-1200)			6 JUN	1703:32	3	-159	6 JUN	2040:57	7	-176	7 JUN	1323:17	23	-170
	1241:02	6	-177		1706:01	4	-169		2055:25	7	-174		1337:03	16	-159
	1241:27	5	-175		1706:32	9	-174		2101:38	8	-175		1338:11	4	-159
	1242:00	5	-175		1709:21	7	-170		2103:15	19	-170		1343:08	13	-159
	1243:00	3	-177		1729:48	6	-169		2133:30	5	-159		1345:13	11	-170
	1244:51	6	-165		1732:52	7	-159		2134:42	8	-174		1348:38	9	-166
	1246:53	19	-175		1734:22	5	-159		2138:52	33	-174		1357:06	4	-159
	1252:00	20	-175		1743:18	20	-165		2142:11	19	-176		1401:23	3	-159
	1343:05	7	-172		1747:56	7	-159		2247:50	13	-159		1452:25	7	-172
	1350:43	29	-170		1750:25	22	-176		2249:25	13	-172		1540:18	5	-174
	1354:55	12	-172		1755:33	23	-159		2256:52	13	-174		1601:32	5	-159
	1357:57	53	-165		1757:00	41	-170		2302:27	9	-164		1609:35	9	-174
	1401:17	19	-169		1804:43	22	-168		2303:18	8	-174		1712:41	25	-175
	1406:34	25	-174		1805:30	8	-171						1718:30	11	-168
	1409:04	20	-168		1834:45	32	-169	7 JUN	0046:47	9	-179		1723:53	10	-173
	1410:30	10	-176		1901:47	8	-165		0056:32	6	-164		1724:51	7	-176
	1412:44	16	-169		1907:09	41	-165		0056:49	9	-176		1726:25	19	-163
	1430:13	12	-174		1953:23	8	-164		1253:44	5	-176		1730:30	23	-173
	1433:06	26	-172		2000:14	13	-169		1255:07	15	-168		1742:57	4	-159
	1433:36	10	-173		2017:45	5	-176		1259:06	5	-168		1802:18	51	-170
	1447:27	14	-174		2018:32	5	-170		1303:32	8	-170		1825:28	60	-170
	1455:00	9	-176		2021:47	4	-175		1313:12	10	-174		1834:50	12	-166
	1459:05	23	-176		2022:10	5	-176		1315:11	37	-171		1836:00	34	-167
	1700:07	10	-168		2025:25	5	-174		1316:55	21	-159		1901:55	6	-174
	1702:20	6	-169		2026:54	19	-166		1321:05	8	-176		1907:29	25	-165

TABLE VII (cont'd)

FLATS DURING PERIOD 6-10 JUN 60

DATE 1960	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1960	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1960	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1960	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw
7 JUN	1922:07	7	-159	8 JUN	1327:49	8	-176	8 JUN	1614:48	6	-170	9 JUN	1305:14	17	-174
	1924:36	13	-176		1328:00	13	-175		1816:56	4	-179		1306:34	8	-164
	1930:40	17	-171		1328:48	5	-170		1827:53	8	-165		1307:28	17	-172
	1941:06	16	-174		1329:15	6	-159		1828:44	2	-171		1311:48	5	-175
	1954:58	9	-169		1337:28	17	-159		1831:15	16	-172		1355:17	8	-179
	1958:45	3	-179		1347:52	5	-159		1832:55	15	-159		1420:25	12	-159
	2002:22	24	-174		1424:15	13	-168		1835:03	4	-175		1429:41	10	-174
	2003:45	20	-159		1426:16	24	-171		1848:30	3	-165		1445:43	16	-171
	2004:28	11	-166		1451:11	79	-168		1849:25	14	-159		1458:04	23	-175
	2006:50	3	-159		1453:59	62	-172		1851:55	5	-159		1616:27	19	-175
	2010:27	6	-170		1459:23	15	-174		1853:55	15	-177		1618:55	8	-175
					1503:00	13	-167		1855:57	13	-175		1620:07	15	-175
8 JUN	(NO DATA 0000-0400)				1504:32	14	-176		1856:26	15	-171		1629:49	18	-175
	0404:00	6	-170		1506:05	26	-179		1904:25	64	-176		1650:58	9	-172
	0405:17	9	-176		1459:43	27	-159		1929:23	20	-175		1704:43	8	-159
	0408:47	25	-174		1518:57	14	-174		1930:44	6	-175		1705:40	9	-159
	0412:52	10	-176		1539:47	27	-172		1930:54	3	-176		1714:26	13	-179
	0414:28	9	-179		1636:13	12	-175						1718:03	5	-175
	(NO DATA 0700-1200)				1636:47	7	-175	9 JUN	0357:27	10	-174		1723:47	13	-174
	1301:10	4	-159		1712:05	23	-176		0414:18	4	-159		1727:55	5	-159
	1307:57	5	-159		1716:33	13	-176		0419:28	9	-179		1743:35	34	-172
	1315:55	13	-159		1810:22	8	-170		0422:44	12	-175		1756:48	15	-172
	1323:38	30	-159		1811:06	9	-168		0422:59	6	-175		1809:56	19	-174
	1326:41	16	-176		1813:13	9	-174		1259:19	6	-175		1814:10	8	-159

TABLE VII (cont'd)

FLATS DURING PERIOD 6-10 JUN 60

DATE 1960	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1960	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1960	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw	DATE 1960	TIME U. T.	DURATION SECS.	PEAK SIGNAL dbw
9 JUN	1814:42	26	-159	10 JUN	1536:46	8	-172	10 JUN	1836:48	16	-172	10 JUN	2023:59	8	-179
	1818:21	10	-172		1542:21	107	-159		1838:01	51	-172		2024:20	3	-159
	1831:40	7	-170		1552:11	5	-165		1854:58	4	-179		2025:28	38	-175
	1832:54	8	-175		1554:15	8	-159		1907:30	7	-176		2027:08	103	-175
	1834:15	10	-175		1602:53	22	-172		1917:40	21	-171		2045:07	6	-159
	1852:39	17	-175		1605:52	74	-168		1922:07	10	-176		2122:42	5	-159
	1854:28	28	-172		1609:00	23	-170		1922:50	15	-174		2126:52	18	-174
	1855:06	14	-175		1626:38	21	-175		1925:30	30	-172		2143:23	27	-166
	1858:16	9	-172		1632:00	85	-159		1927:58	11	-175		2151:02	7	-179
	2255:44	6	-183		1646:10	12	-174		1936:17	62	-165		2201:00	41	-170
	2306:46	14	-183		1755:35	11	-168		1943:23	30	-159		2240:47	10	-171
					1759:12	7	-170		1946:45	34	-179		2241:46	8	-172
10 JUN	(NO DATA 0000-1200)				1759:55	11	-179		1952:47	27	-163		2243:06	12	-179
	1304:25	24	-169		1800:32	11	-172		1954:54	6	-174		2247:58	24	-173
	1409:11	12	-161		1803:08	4	-174		2007:23	40	-175		2255:02	33	-170
	1505:23	26	-171		1805:13	4	-177		2008:10	39	-165		2300:28	14	-174
	1509:39	14	-172		1806:34	9	-166		2010:46	29	-179		2308:07	29	-168
	1510:17	7	-159		1813:35	50	-170		2011:37	16	-179		2310:48	74	-159
	1510:37	67	-172		1814:59	61	-170		2014:35	43	-174		2315:16	17	-174
	1518:24	8	-172		1817:29	38	-172		2015:50	21	-166		2318:10	7	-165
	1521:06	22	-172		1824:59	17	-172		2016:23	43	-175		2323:21	95	-159
	1521:43	9	-173		1825:55	13	-176		2018:44	40	-175		2348:52	17	-172
	1523:43	24	-173		1829:47	13	-172		2020:21	31	-179				
	1533:03	28	-173		1836:14	15	-168		2021:47	58	-174				

TABLE VIII - SATELLITE PASSES AND CORRELATED FLATS

Fig No.	Period Examined	Number of Satellite Passes in Period	Number of Correlations*	Identification of Correlations
20	22-26 Jul 59	11	0	
21	13-17 Sep 59	13	5	58 Delta 2 (2) 59 Epsilon 1 (3)
22	15-21 Dec 59	6	5	58 Delta 2 (5)
23	12-16 Jan 60	6	4	58 Delta 2 (4)
24	31 Mar-6 Apr 60	6	2	58 Delta 2 (1), 60 Beta 1 (1)
25	6-10 Jun 60	10	1	60 Epsilon 2 (1)

* Correlation denotes a minimum of two flats occurring in the period from 10 minutes before pass time until 20 minutes after pass time.

and a distribution characterized by small, compact groups separated by long periods of little or no activity. Such a distribution might indicate that these flats were caused by a distinct event, such as the movement of a satellite or meteor shower.

To examine the relationship between satellite altitude and flats, a tabulation was made of all flats occurring in a 30-minute period* in the vicinity of each of the underlined satellite passes in Figures 20-25. These data are presented in Table IX.

Regarding the effect of satellite altitude on the formation of flats, it is noted that of the 67 satellite reflections recorded by the DOPLOC center antenna, 17 (or 25%) show evidence of flats near the satellite pass time (see Table I). These 17 satellite passes have an average altitude of 184 miles. It cannot be concluded from these data, however, that flats are more frequently associated with the lower altitude satellites, since the average altitude of all the center antenna satellite reflections is only 201 miles. The range limitations of the interim DOPLOC system made reception of the higher altitude passes marginal and, consequently, the satellite reflections that were received were from the lower altitude passes.

In Figures 20-25, however, there are a total of 52 satellite passes charted, ranging in altitude from 95 to 658 miles. These passes represent all of the satellite crossings that were predicted for the DOPLOC system during these periods. Of these 52 passes, 17 (or 33%) show evidence of several flats near satellite pass time and the average altitude of these 17 satellite passes is 332 miles (see Table IX). It should be pointed out that the limitations of the DOPLOC system do not apply here, since we are concerned only with observations of flats, as opposed to flats and satellites. Since flats are assumed to be considerably larger than the associated satellite, it is felt that reflections would be obtained from flats at high altitudes even though no reflection would be received from the satellite itself.

* From 10 minutes before pass time until 20 minutes after pass time.

Comparison of the data in Tables I and IX indicates that formation of flats is apparently not entirely dependent on altitude, since by more than tripling the altitude range of the data examined, the flats observed only increased by approximately 8%. Based on these data, it would appear that flats may be observed almost as frequently associated with satellites at low altitudes as at high altitudes.

TABLE IX - SATELLITE ALTITUDE VS NUMBER OF FLATS

Date	Satellite	Altitude Miles	Number of Flats, in 30-Min. Period
14 Sep 59	58 Delta 2	430	2
17 Sep 59	58 Delta 2	658	3
15 Dec 59	58 Delta 2	492	6
16 Dec 59	58 Delta 2	485	7
17 Dec 59	58 Delta 2	482	12
18 Dec 59	58 Delta 2	478	3
21 Dec 59	58 Delta 2	194	4
12 Jan 60	58 Delta 2	410	5
13 Jan 60	58 Delta 2	186	7
14 Jan 60	58 Delta 2	186	2
16 Jan 60	58 Delta 2	401	11
4 Apr 60	58 Delta 2	95	2
13 Sep 59	59 Epsilon 2	210	4
14 Sep 59	59 Epsilon 2	147	3
16 Sep 59	59 Epsilon 2	140	2
5 Apr 60	60 Beta 1	451	10
6 Jun 60	60 Epsilon 2	201	5
Average		332	

*From 10 minutes before pass time until 20 minutes after pass time.

C. Meteor-Induced Ionization

Reflections from meteor trails may account for some of the flats observed, particularly in the December and June samples (Figures 22 and 25). The Ursid meteor shower normally occurs during the period 17-24 December with the maximum activity on 22 December. During this maximum, a radio-observed rate of 13 meteors/hour has been reported.¹⁰

Similarly, the daytime Arietid and daytime Perseid showers reach their maximum on 8 June and 9 June, respectively, which would place them in the interval charted in Figure 25. For these showers, the maximum hourly radio-observed meteor rate is 66 and 42, respectively.

A meteor passing through the ionosphere forms initially a large, cylindrical, ionized column, and maximum reflection or signal scattering is experienced when the incident wave is normal to the long axis of the cylinder. The passage of a great number of meteors (as in a shower) could quite conceivably form many large, ionized columns which, upon diffusion, would overlap and effectively blanket a considerable area with a slow moving ionized cloud. From a cloud of this type having a reasonably uniform density, we might expect to observe a single, continuous, long duration flat with a strong signal level. However, if the cloud was patchy and non-uniform, then the reflections received might be intermittent, with shorter durations and varying signal strengths.

V. CONCLUSIONS

Based on the data presented in this report, several conclusions appear rather firm. First, when a flat is observed in connection with a known satellite passage, the signal level received from the flat is usually stronger than the signal level received from the associated satellite. This would indicate that the dimensions of the reflecting mass are comparable to or larger than those of the satellite.

Secondly, satellite passage cannot be accurately determined by merely charting the occurrence of flats against a time reference. The appearance of a large number of flats in a short time is not a reliable indication that a satellite has passed, evidenced by the data presented in Figures 22-24. Attention is called to the many groups of flats, not associated with a satellite crossing, which appear very similar to those groups of flats observed in the vicinity of a satellite pass.

Thirdly, satellite altitude does not appear to be a factor in the formation or detection of flats. The DOPLOC system recorded flats associated with satellites at various altitudes, ranging from 110 miles to more than 600 miles.

Harold T. Lootens

HAROLD T. LOOTENS

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2. de Bey, L. G., Richard, V. W., Patton, R. B. Second Semi-Annual Technical Summary Report, Period 1 January 1959 - 30 June 1959. BRL Memo Report No. 1220 (1959).
3. de Bey, L. G. Third Technical Summary Report, Period 1 July 1959 - 30 June 1960. BRL Memo Report No. 1287 (1960).
4. Hodge, A. H. Final Summary Report on the BRL-DOPLOC Project. BRL Report No. 1136 (1961).
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4. S. Rand, "Wake of a Satellite Traversing the Ionosphere," Phys. of Fluids, Vol. 3, 265-273, Mar - Apr 1960.
5. E. H. Walker, S. F. Singer, "Wake of a Charged Body Moving in a Plasma," Bull. Am. Phys. Soc., Vol. 5, 234, Apr 1960.
6. G. D. Magnuson, D. B. Medved, "Sputtering as a Mechanism for Increase of Ionization in the Vicinity of Low Altitude Satellites," Phys. Sec. Convair, San Diego, California, Rept. No. ZPh-050, II-227, Dec 1959.
7. L. Liszka, B. Hultquist, "Investigations of Radio Transmissions from 1958 Delta 2 (Sputnik III) made at Kiruna Geophysical Observatory," Feb 1961.
8. C. Roberts, P. Kirchner, D. Bray, "Radio Detection of Silent Satellites," QST, Vol. 43, 34-35, Aug 1959.
9. T. G. Hame, W. D. Stuart, "Detection of Satellites by their Influence on the Ionosphere," Paper presented at joint URSI-IRE meeting, Boulder, Colorado, Dec 1960.

APPENDIX I

BRL-DOPLOC REPORTS

No. 1 BRL Memo Report No. 1055 - October 1958
"Doppler Signals and Antenna Orientation for a Doppler System"
by L. P. Bolgiano, Jr., CONFIDENTIAL

No. 2 BRL Memo Report No. 1185 - January 1959
First Semi-Annual Technical Summary Report
Period 1 July 1958 - 31 December 1958
by L. G. deBey, V. W. Richard, A. H. Hodge, R. B. Patton, C. L. Adams.,
(BML 39-60) CONFIDENTIAL

No. 3 BRL Tech Note No. 1265 - June 1959
"Orbital Data Handling and Presentation"
by R. E. A. Putnam., UNCLASSIFIED

No. 4 BRL Tech Note No. 1266 - July 1959
"An Approach to the Doppler Dark Satellite Detection Problem"
by L. G. deBey., CONFIDENTIAL

No. 5 BRL Memo Report No. 1220 - July 1959
Second Semi-Annual Technical Summary Report
Period 1 January - 30 June 1959
by L. G. deBey, V. W. Richard and R. B. Patton.,
(BML 208-59) CONFIDENTIAL

No. 6 BRL Tech Note No. 1278 - September 1959
"Synchronization of Tracking Antennas"
by R. E. A. Putnam., UNCLASSIFIED

No. 7 BRL Memo Report No. 1237 - September 1959
"A Method of Solution for the Determination of Satellite Orbital
Parameters from DOPLOC Measurements"
by R. B. Patton, Jr., UNCLASSIFIED

No. 8 BRL Memo Report No. 1093 - March 1960
"The Dynamic Characteristics of Phase-Lock Receivers"
by Dr. Keats Pullen., UNCLASSIFIED

No. 9 "Station Geometry Studies for the DOPLOC System"
Stanford Research Institute., UNCLASSIFIED

No. 10 Final Report, Part B, Stanford Research Institute - July 1960
"DOPLOC System Studies"
by W. E. Scharfman, H. Rothman, H. Guthart, T. Morita., UNCLASSIFIED

No. 11 Philco Corporation - 4 May 1960
"Polystation Doppler System", UNCLASSIFIED

BRL-DOPLOC REPORTS (cont'd)

No. 12 Space Science Laboratory, General Electric Co. - October 1960
"Orbit Determination of a Non-Transmitting Satellite Using Doppler Tracking Data"
by Dr. Paul B. Richards., UNCLASSIFIED

No. 13 Final Technical Report - University of Delaware - June 15, 1960
"Quantum Mechanical Analysis of Radio Frequency Radiation"
by L. P. Bolgiano, Jr. and W. M. Gottschalk., UNCLASSIFIED

No. 14 Final Report F/157, Columbia University - February 11, 1960
"Summary of the Preliminary Study of the Applicability of the Ordin System Techniques to the Tracking of Passive Satellites", UNCLASSIFIED

No. 15 BRL Report No. 1110 - June 1960
"Precision Frequency Measurement of Noisy Doppler Signals"
by W. A. Dean., UNCLASSIFIED

No. 16 Third Technical Summary Report - Period July 1959 through June 30, 1960
BRL Memo Report No. 1287
by A. L. G. deBey., UNCLASSIFIED

No. 17 Columbia University Tech. Report No. T-1/157 - August 1, 1959
"The Theory of Phase Synchronization of Oscillators with Application to the DOPLOC Tracking Filter"
by E. Kreindler., UNCLASSIFIED

No. 18 BRL Tech Note No. 1345 - August 1960
"DOPLOC Receiver for Use with Circulating Memory Filter"
by K. Patterson., UNCLASSIFIED

No. 19 BRL Tech Note No. 1354 - October 1960
"Parametric Pre-Amplifier Results"
by K. Patterson., UNCLASSIFIED

No. 20 BRL Tech Note No. 1367 - December 1960
"Data Generation and Handling for Scanning DOPLOC System"
by Ralph E. A. Putnam

No. 21 BRL Report No. 1123 - January 1961
"The DOPLOC Instrumentation System for Satellite Tracking"
by C. L. Adams., UNCLASSIFIED

No. 22 BRL Memo Report No. 1330 - March 1961
"DOPLOC Observations of Reflection Cross Sections of Satellites"
by H. T. Lootens., UNCLASSIFIED

No. 23 BRL Memo Report No. 1362 - August 1961
"Satellite-Induced Ionization Observed With the DOPLOC System"
by H. T. Lootens., UNCLASSIFIED

BRL-DOPLOC REPORTS (cont'd)

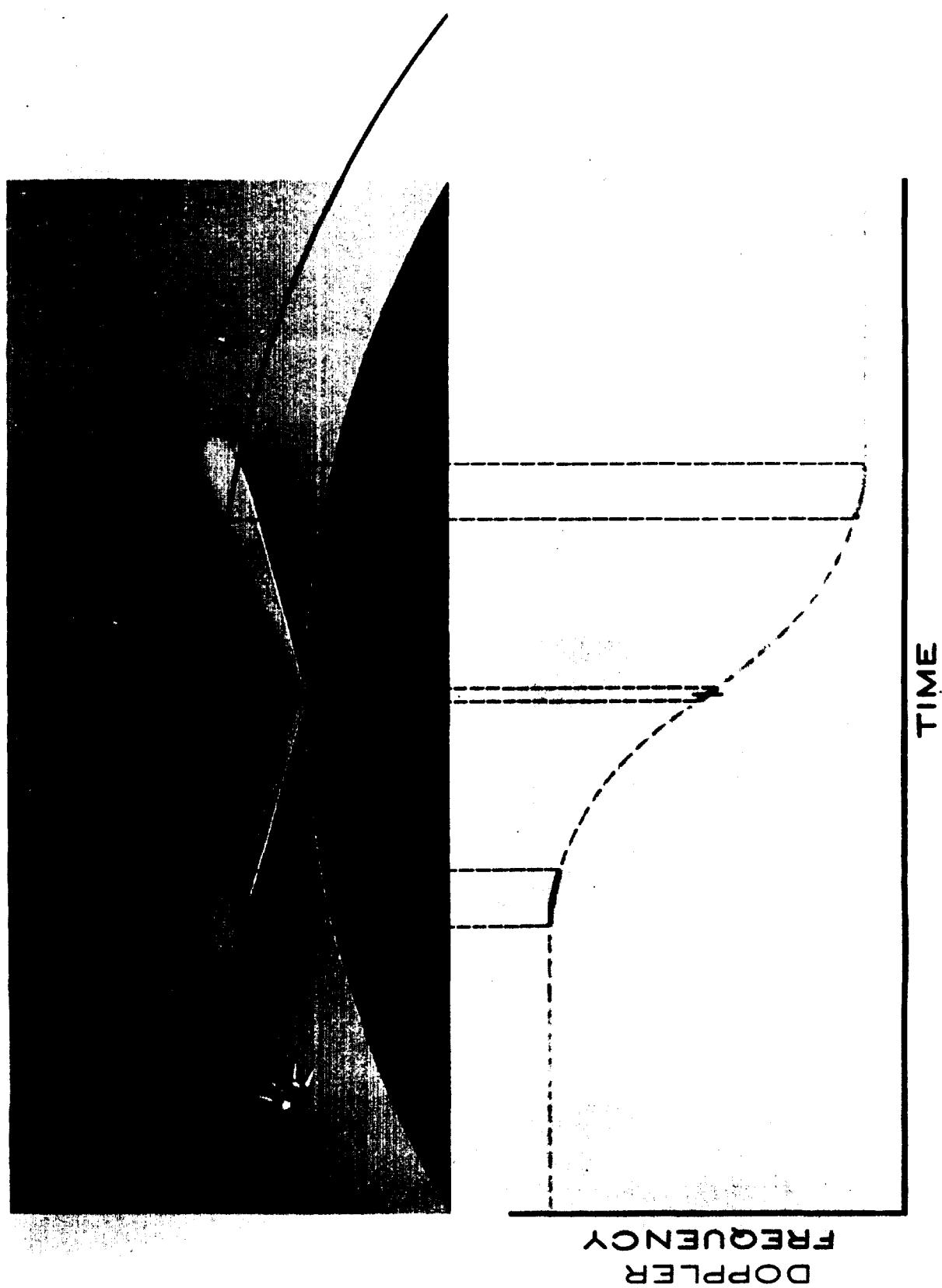
In Preparation

No. 24 "DOPLOC Comb Filter" by R. Vitek

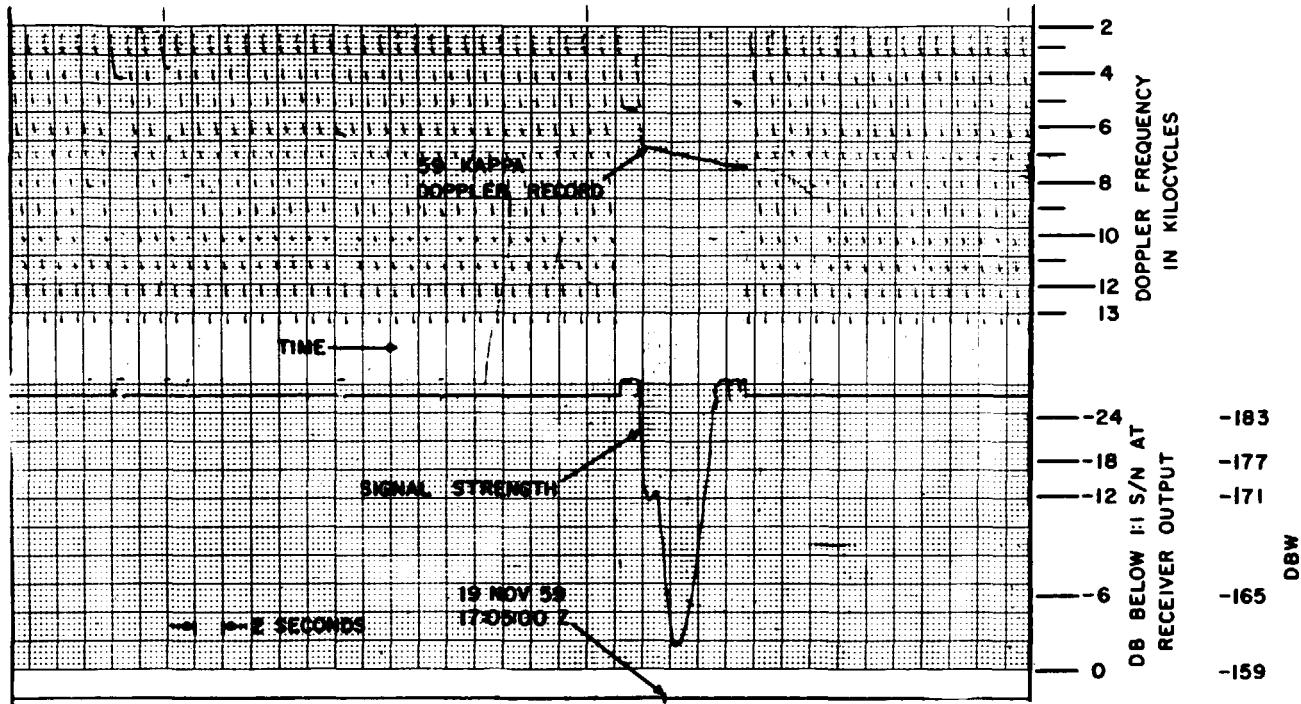
No. 25 "Final Summary Report on the BRL-DOPLOC Project"
by Dr. A. H. Hodge

BASIC INTERIM DOPLOC SYSTEM

Fig. 1

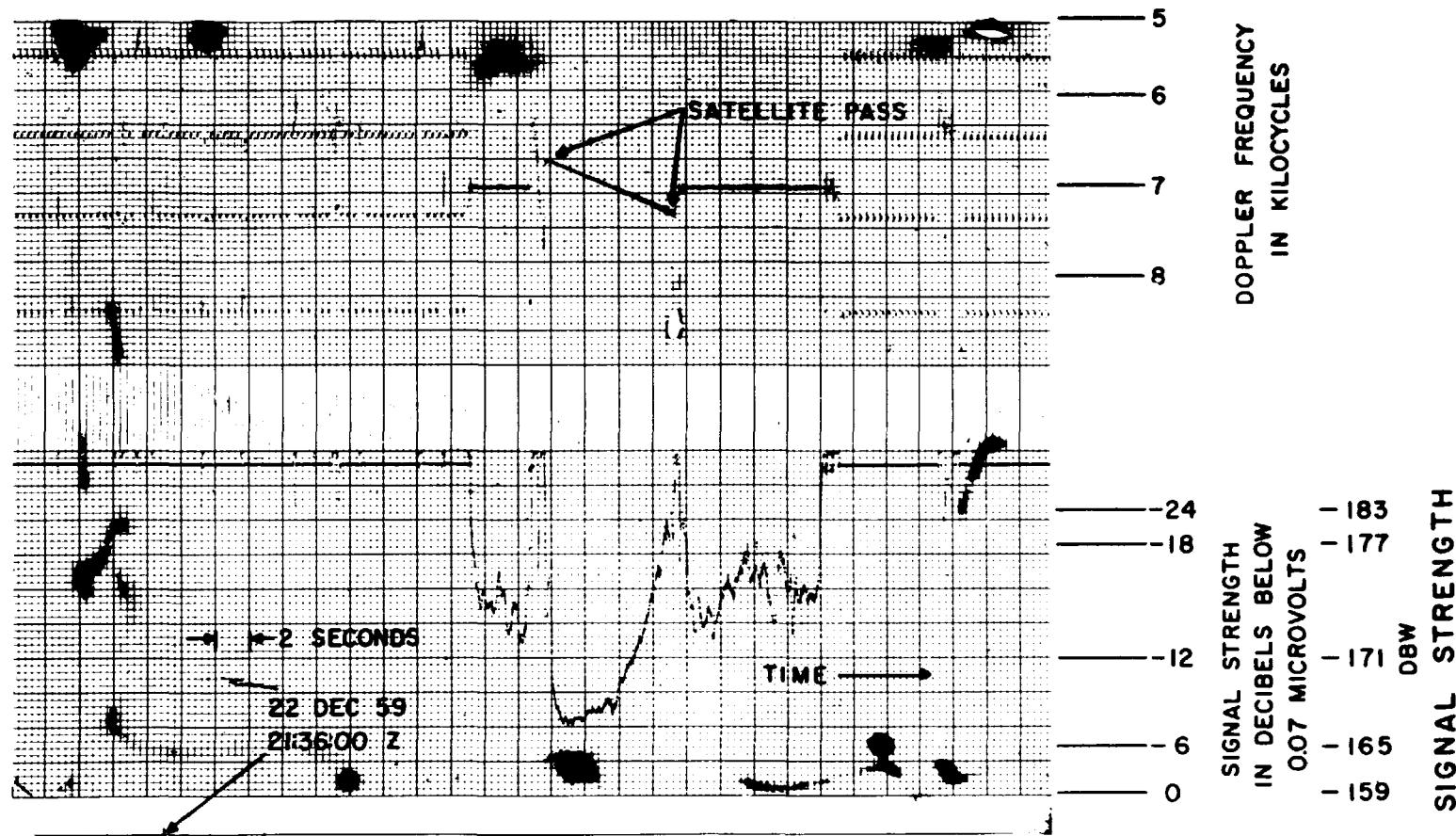


Z	TIME	PERIOD
1	7 0 5 0 4 1 3 3 7 4	
1	7 0 5 0 3 1 3 6 0 7	
1	7 0 5 0 2 1 3 8 1 3	
1	7 0 5 0 1 1 4 0 2 7	
1	7 0 5 0 0 1 4 2 4 7	
1	7 0 4 5 9 1 4 4 7 2	
DIGITAL DOPPLER PERIOD PRINT RECORD		



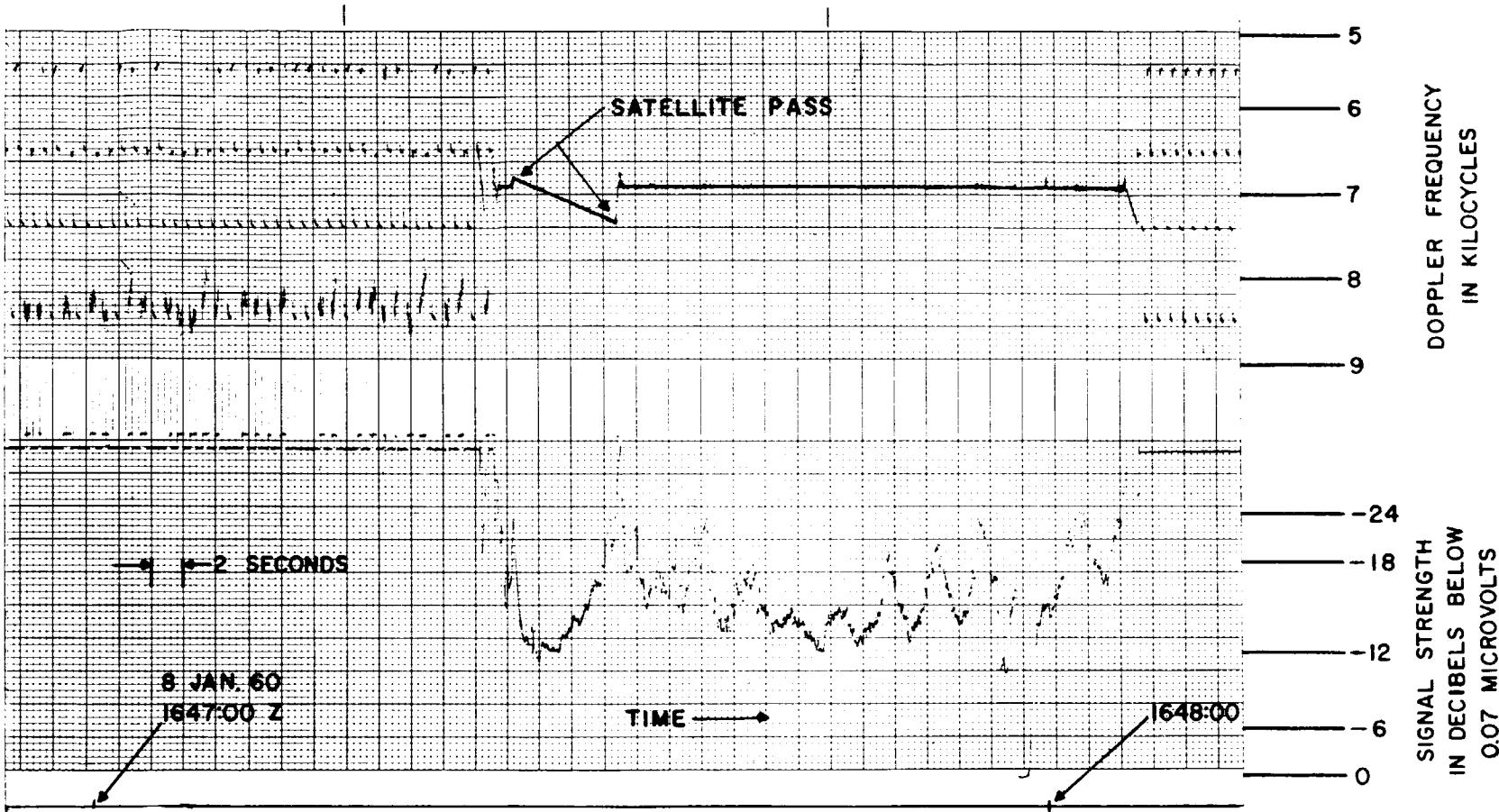
ARPA - BRL DOPLOC DOPPLER RECORD OF
59 KAPPA REV 183 FORREST CITY, ARKANSAS
MEASURED 17:04:58 Z, PREDICTED 17:06 Z
ALTITUDE 115 MILES, 314 MILES EAST FT. SILL
CENTER ANTENNA, NORTH-SOUTH PASS

Fig. 2



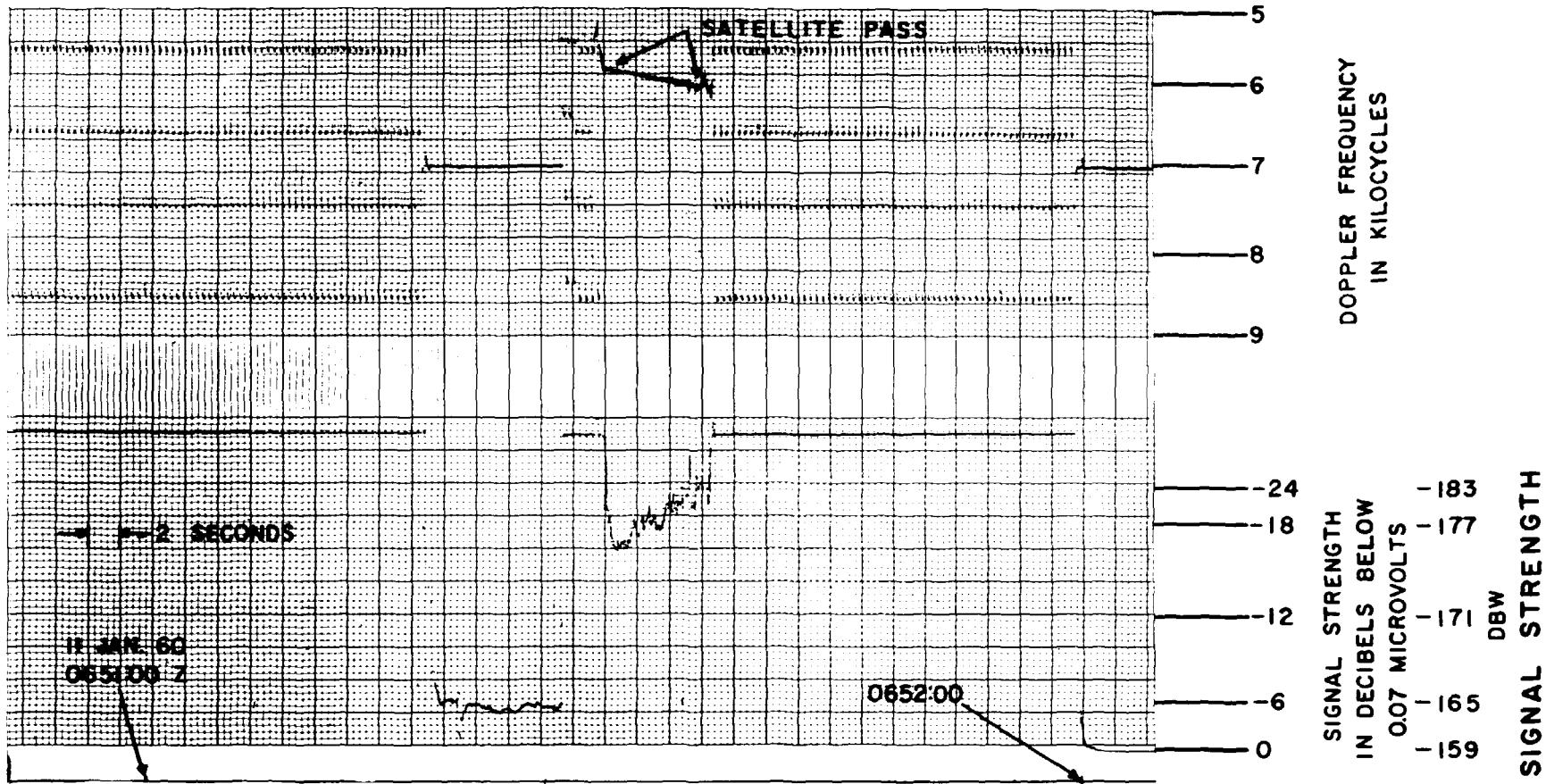
ARPA - BRL DOPLOC DOPPLER RECORD OF
58 DELTA REV 8386 FORREST CITY, ARKANSAS
MEASURED 21:36:23 Z, PREDICTED 21:32 Z
ALTITUDE 172 MILES, 176 MILES EAST FT. SILL
CENTER ANTENNA, N-S PASS

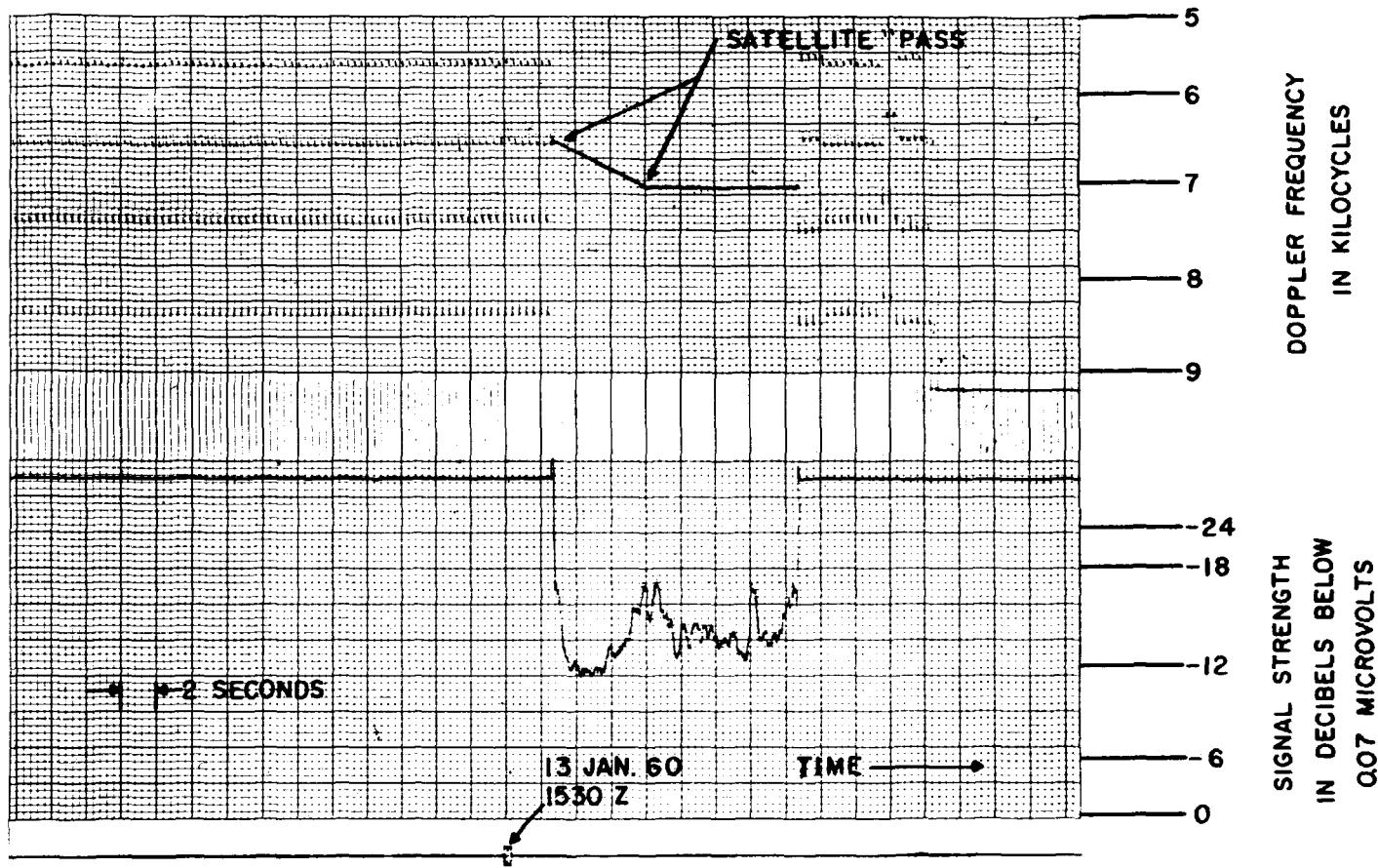
Fig. 3



ARPA-BRL DOPLOC DOPPLER RECORD OF
58 DELTA REV. 8643, FORREST CITY, ARKANSAS
MEASURED 1647:25 Z, PREDICTED 1647 Z
ALTITUDE 156 MILES, 139 MILES EAST FT. SILL
CENTER ANTENNA, NORTH-SOUTH PASS

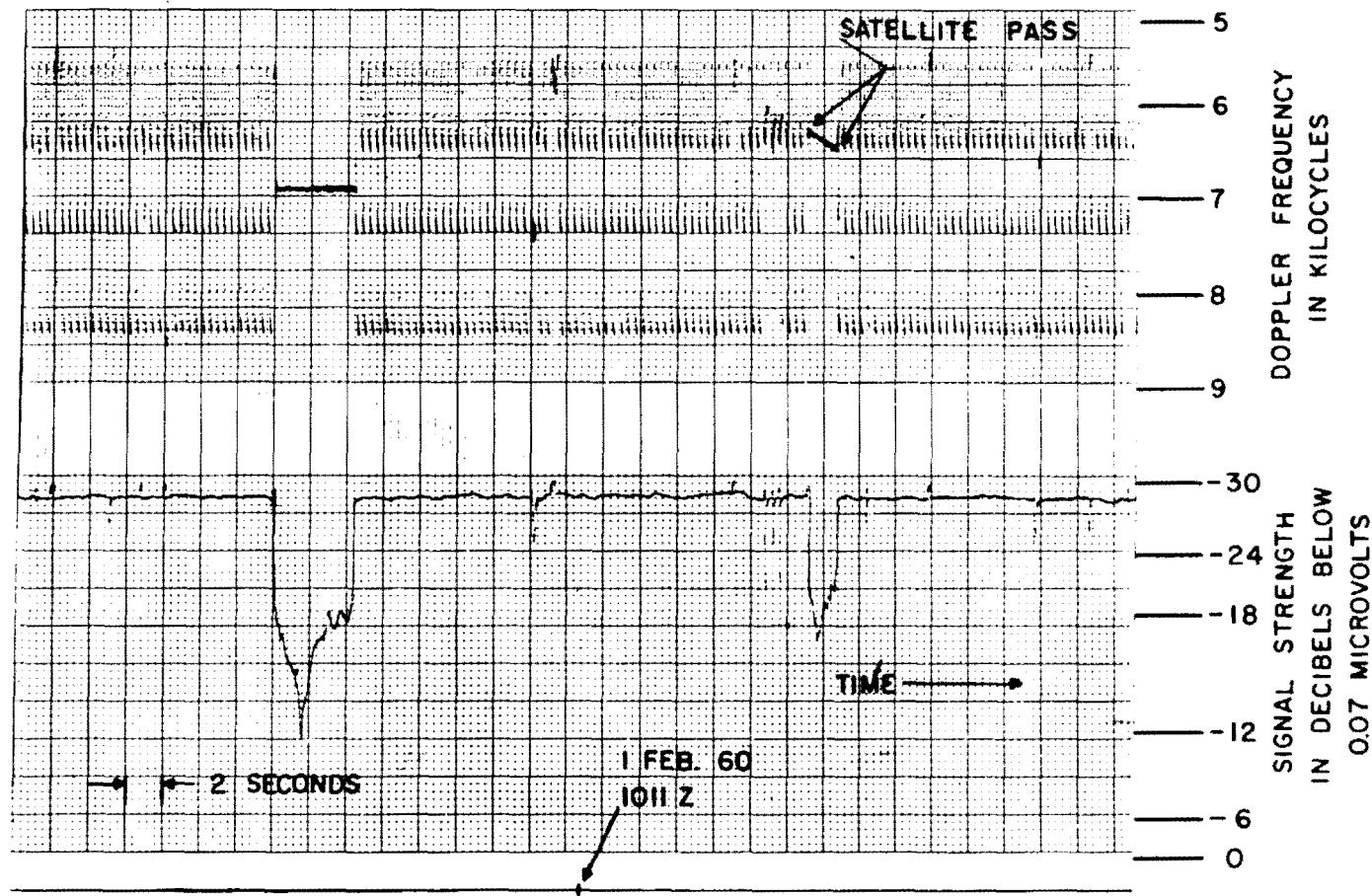
Fig. 4





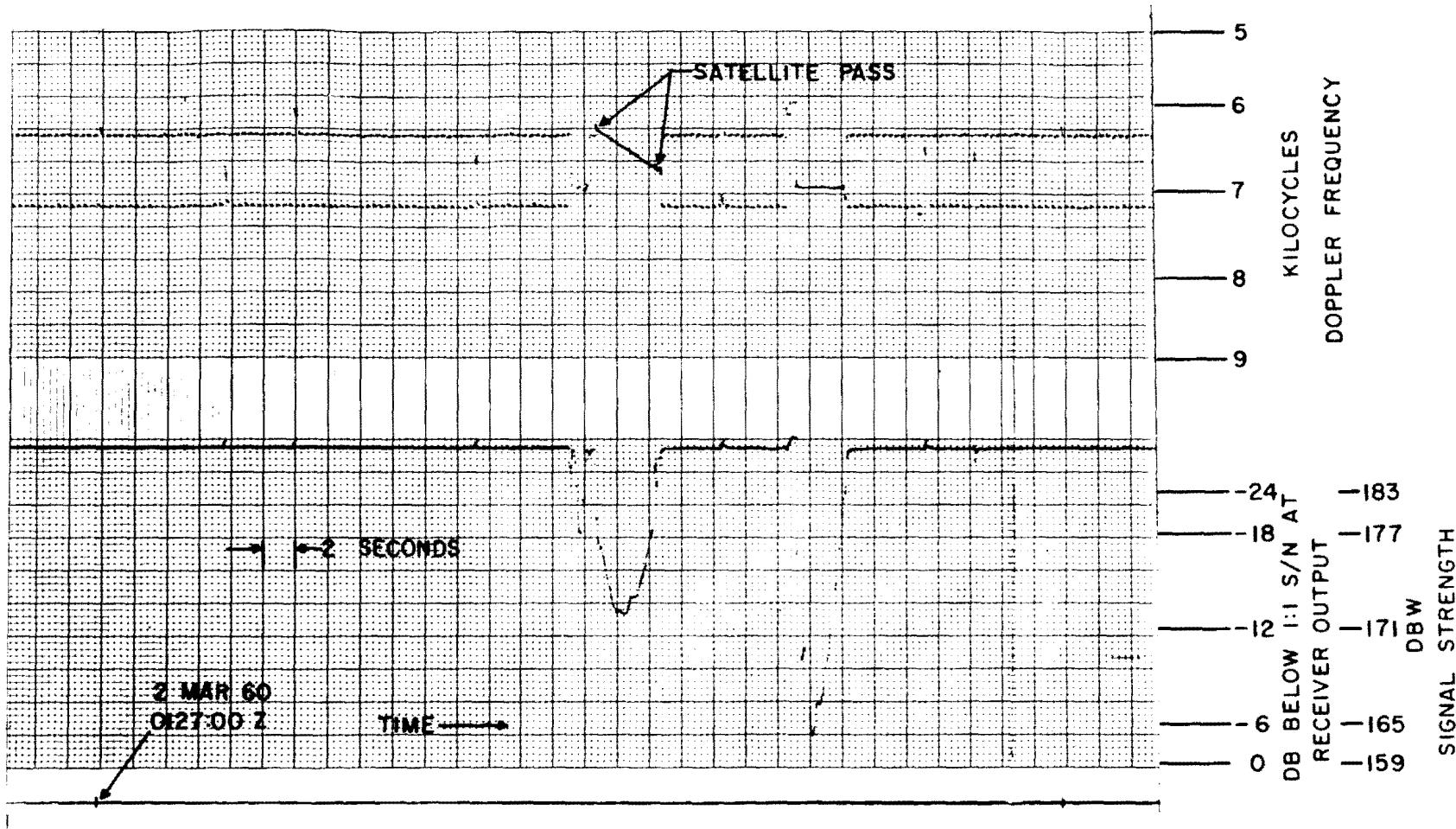
ARPA-BRL DOPLOC DOPPLER RECORD OF
58 DELTA REV. 8719, FORREST CITY, ARKANSAS
MEASURED 1530:03 Z, PREDICTED 1528 Z
ALTITUDE 186 MILES, 50 MILES EAST FT. SILL
CENTER ANTENNA, NORTH - SOUTH PASS

Fig. 6



ARPA - BRL DOPLOC DOPPLER RECORD OF
58 DELTA REV. 9009, FORREST CITY, ARKANSAS
MEASURED 1011:12 Z, PREDICTED 1009 Z
ALTITUDE 134 MILES, 46 MILES WEST FT. SILL
CENTER ANTENNA, NORTH-SOUTH PASS

Fig. 7



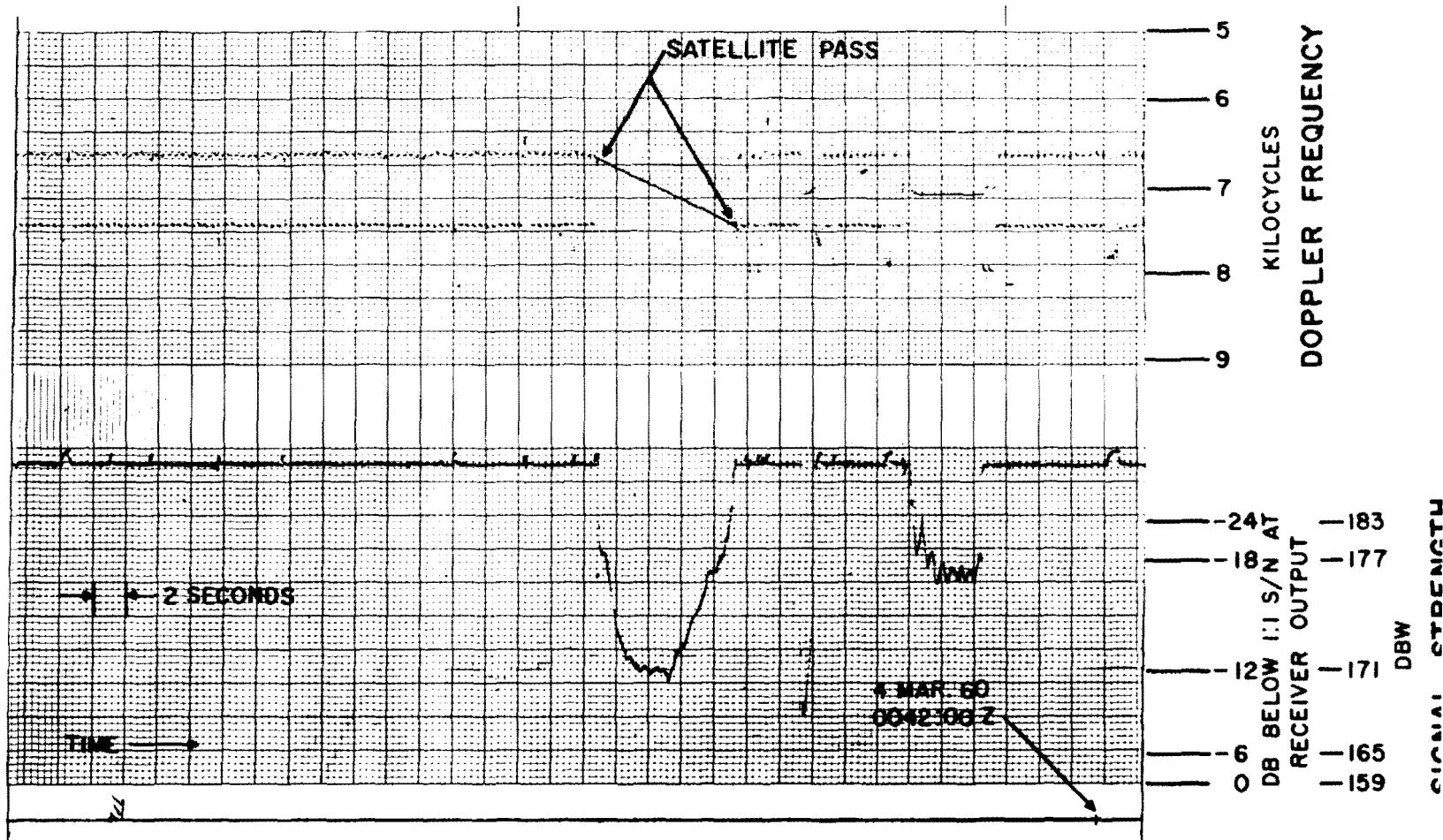
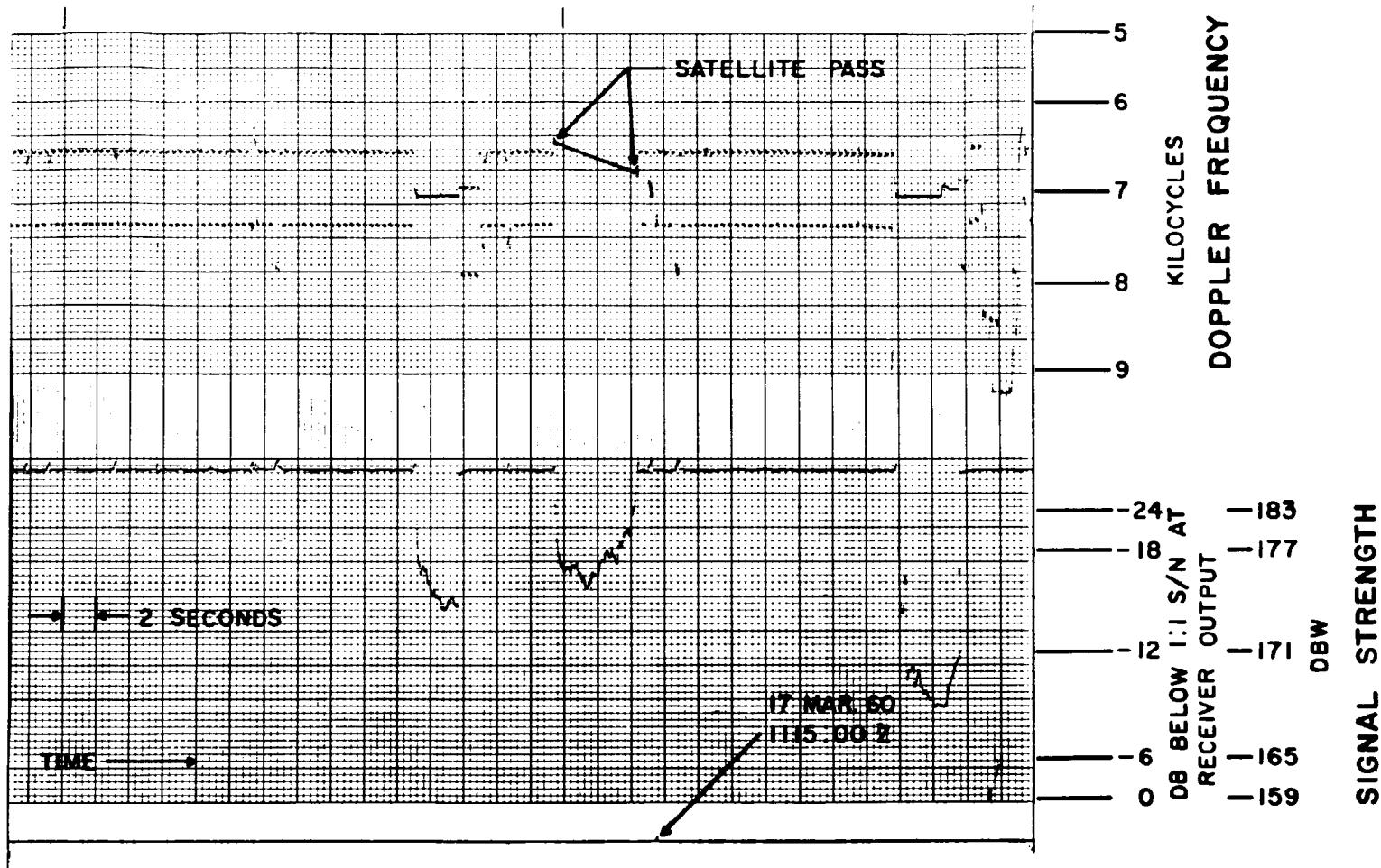


Fig. 9



ARPA-BRL DOPLOC DOPPLER RECORD OF
58 DELTA REV 9716, FORREST CITY, ARKANSAS
MEASURED 1114:54 Z, PREDICTED 1116 Z
ALTITUDE 285 MILES, 135 MILES EAST FT. SILL
CENTER ANTENNA, SOUTH-NORTH PASS

Fig. 10

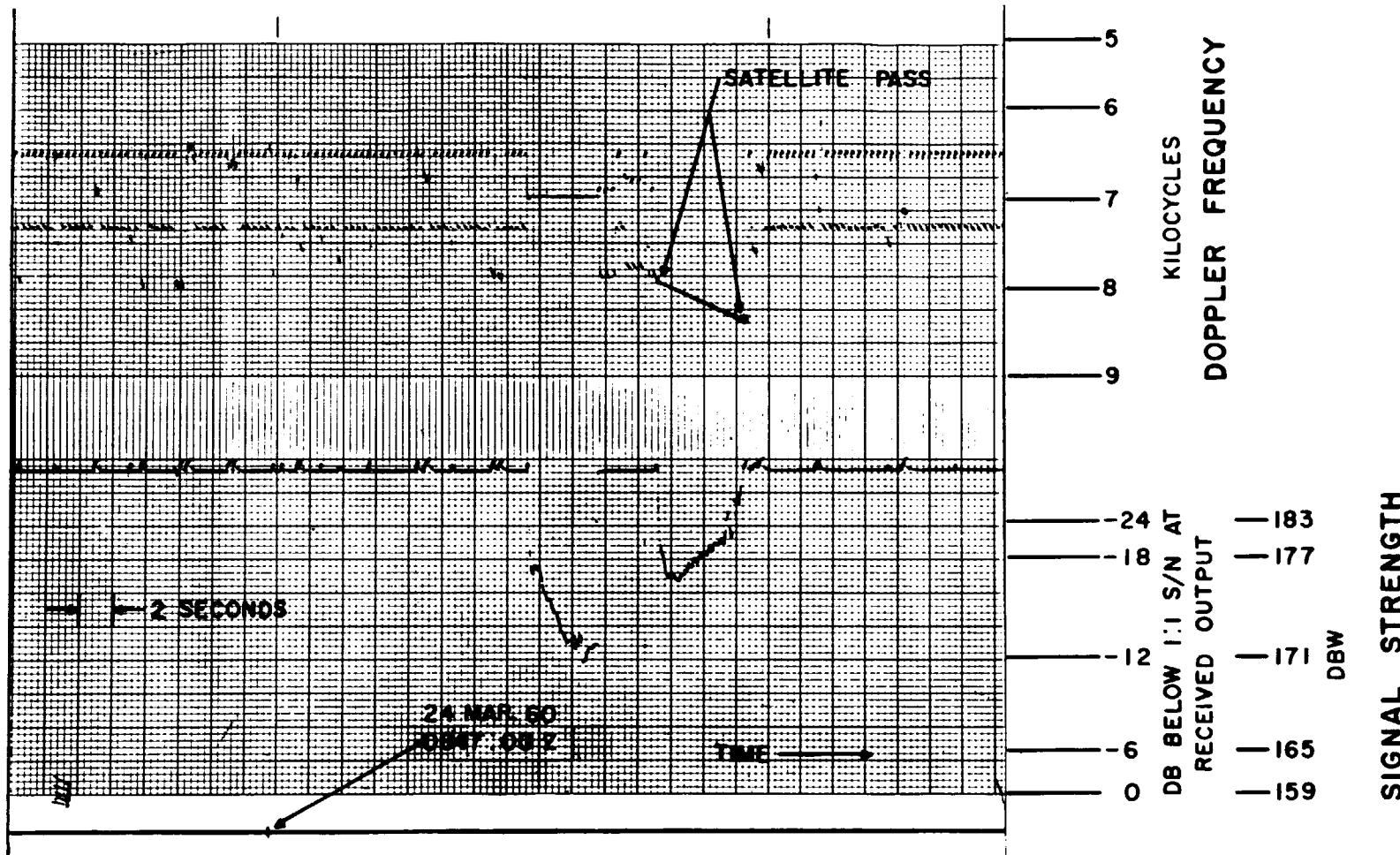
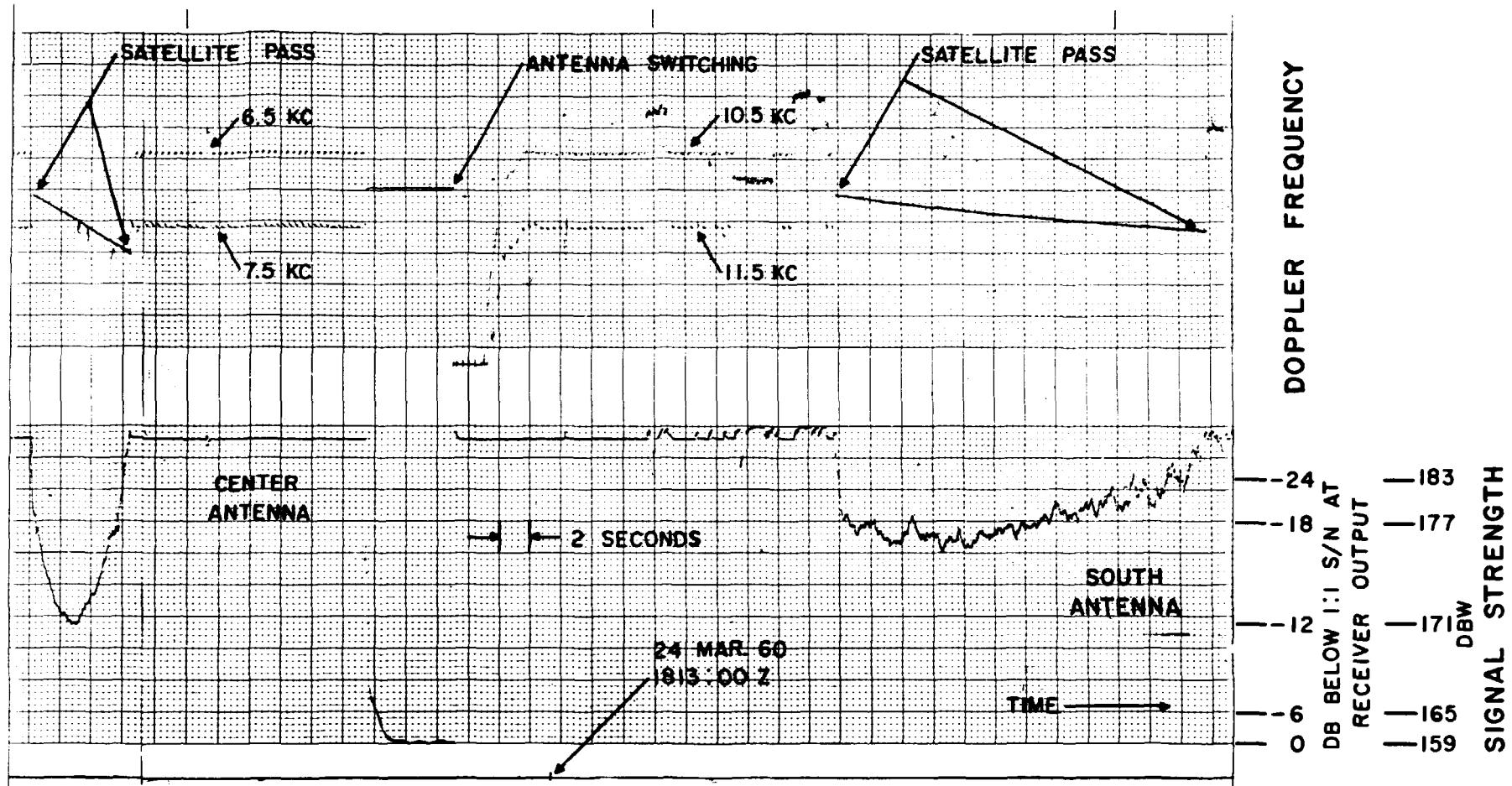
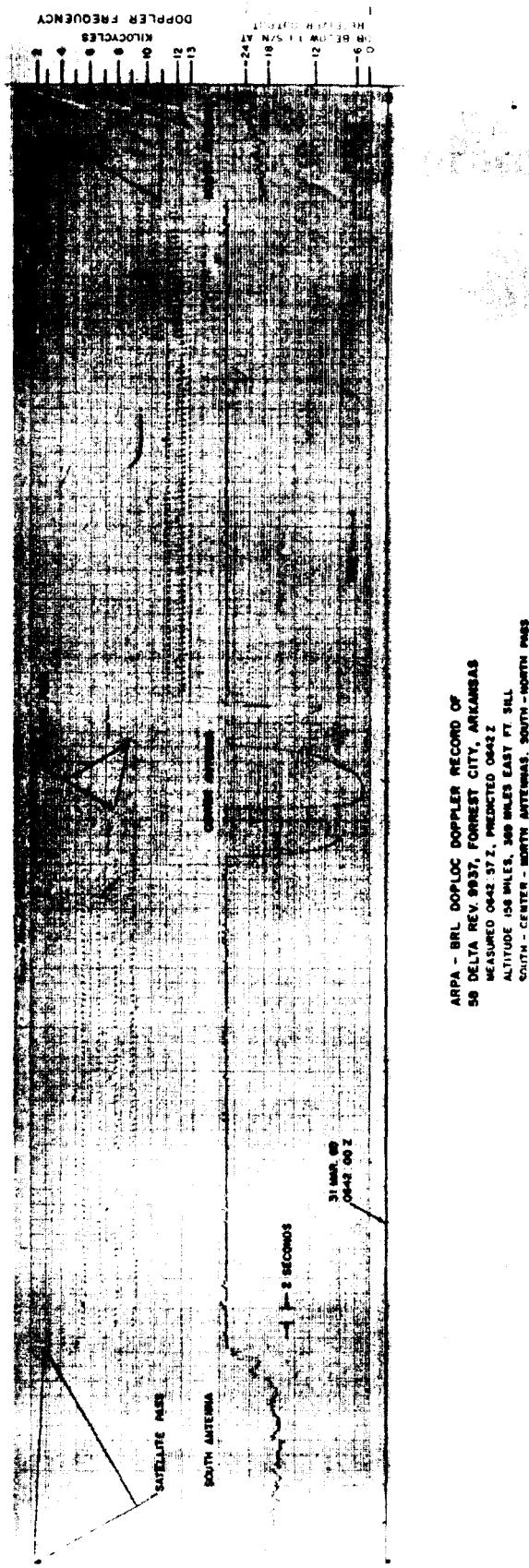


Fig. 11



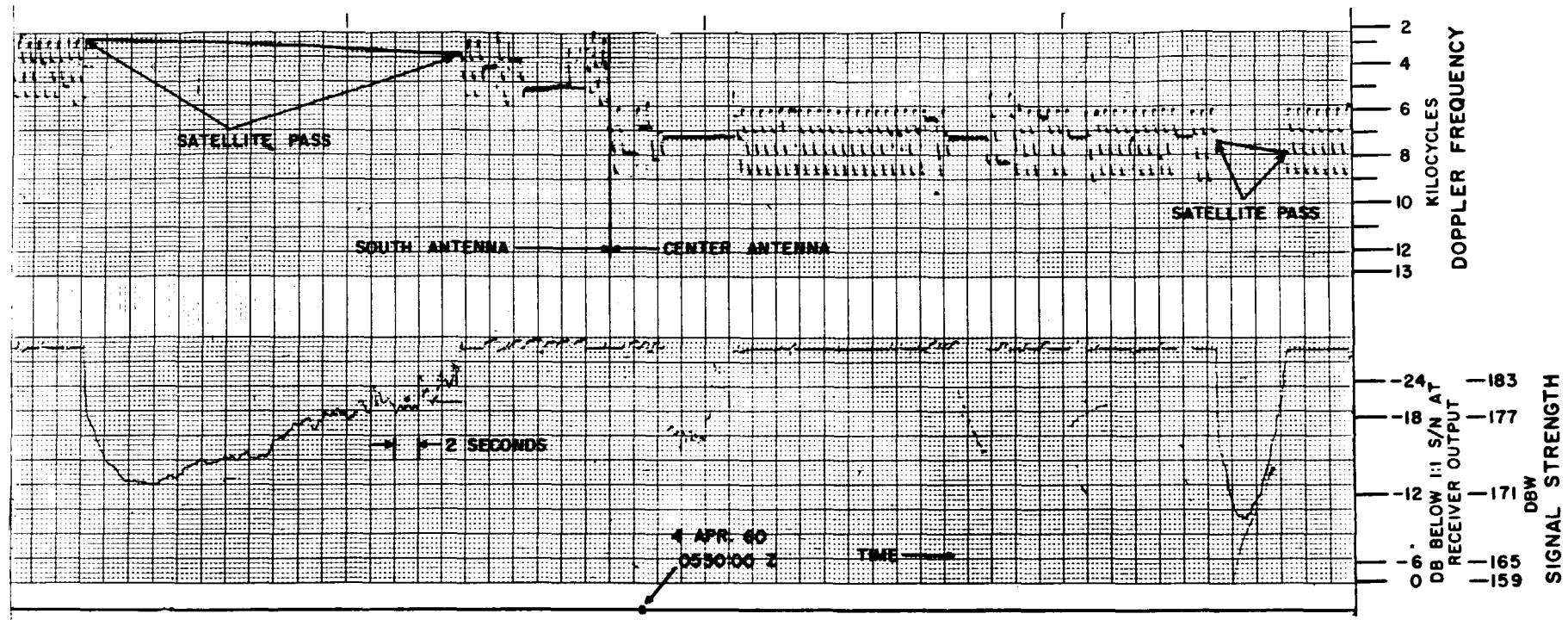
ARPA - BRL DOPLOC DOPPLER RECORD OF
58 DELTA REV 9832, FORREST CITY, ARKANSAS
MEASURED 1812:26 Z, PREDICTED 1813 Z
ALTITUDE 110 MILES, 244 MILES EAST FT. SILL
CENTER AND SOUTH ANTENNA, NORTH - SOUTH PASS

Fig. 12



ARPA - BIRL DOPPLER RECORD OF
50 DELTA REV. 9937, FORREST CITY, ARKANSAS
MEASURED 0442 37Z, PREDICTED 0442 22
ALTITUDE 156 MILES, 369 MILES EAST 17° SELL
SOUTH CENTER - NORTH ANTENNA, SOUTH - NORTH MODE

Fig. 13



ARPA-BRL DOPLOC DOPPLER RECORD OF
58 DELTA REV. 10001, FORREST CITY, ARKANSAS
 MEASURED 0530:49 Z, PREDICTED 0537 Z
 ALTITUDE 124 MILES, 285 MILES EAST OF FT. SILL
 SOUTH AND CENTER ANTENNAS, SOUTH-NORTH PASS

Fig. 14

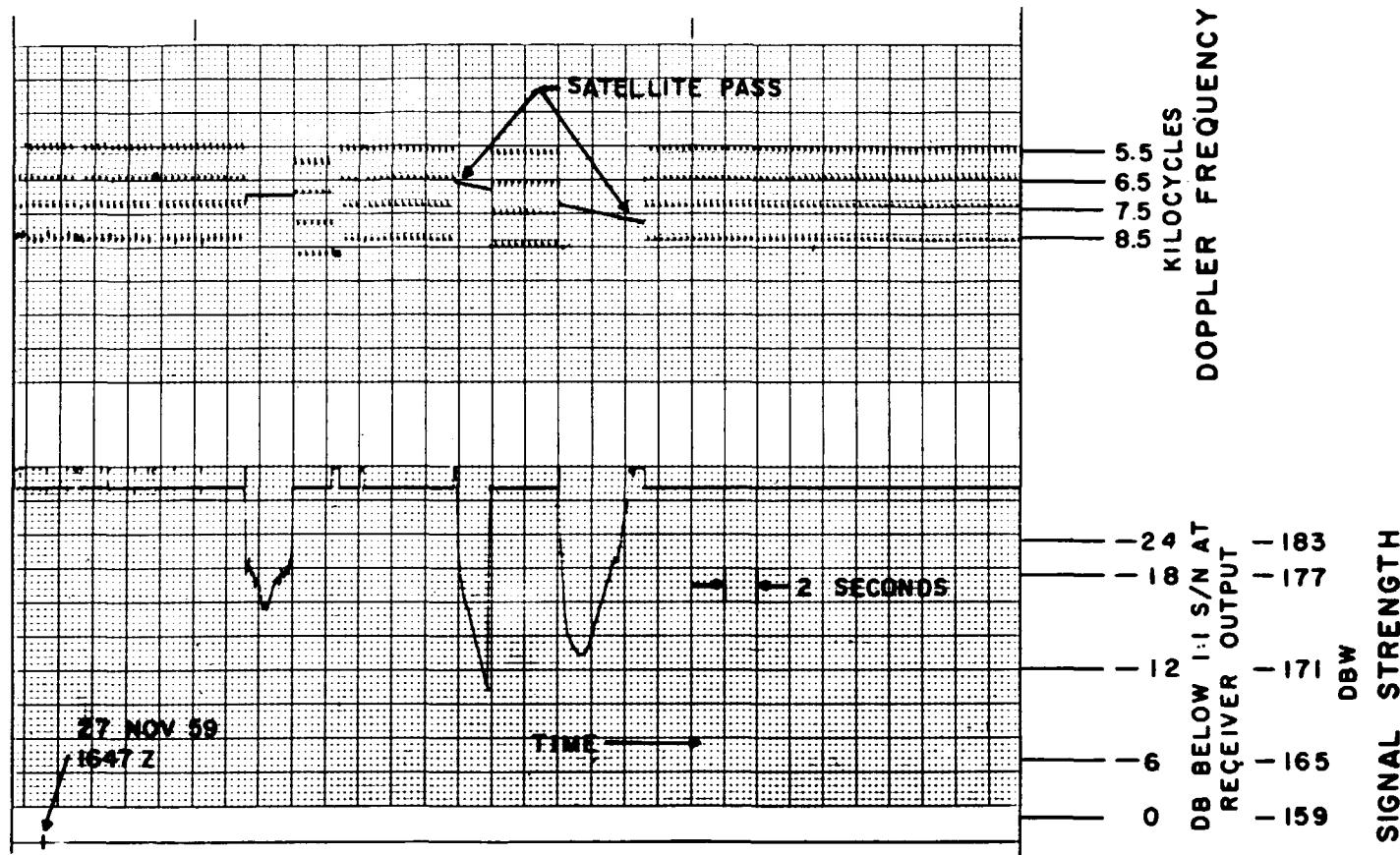


Fig. 15

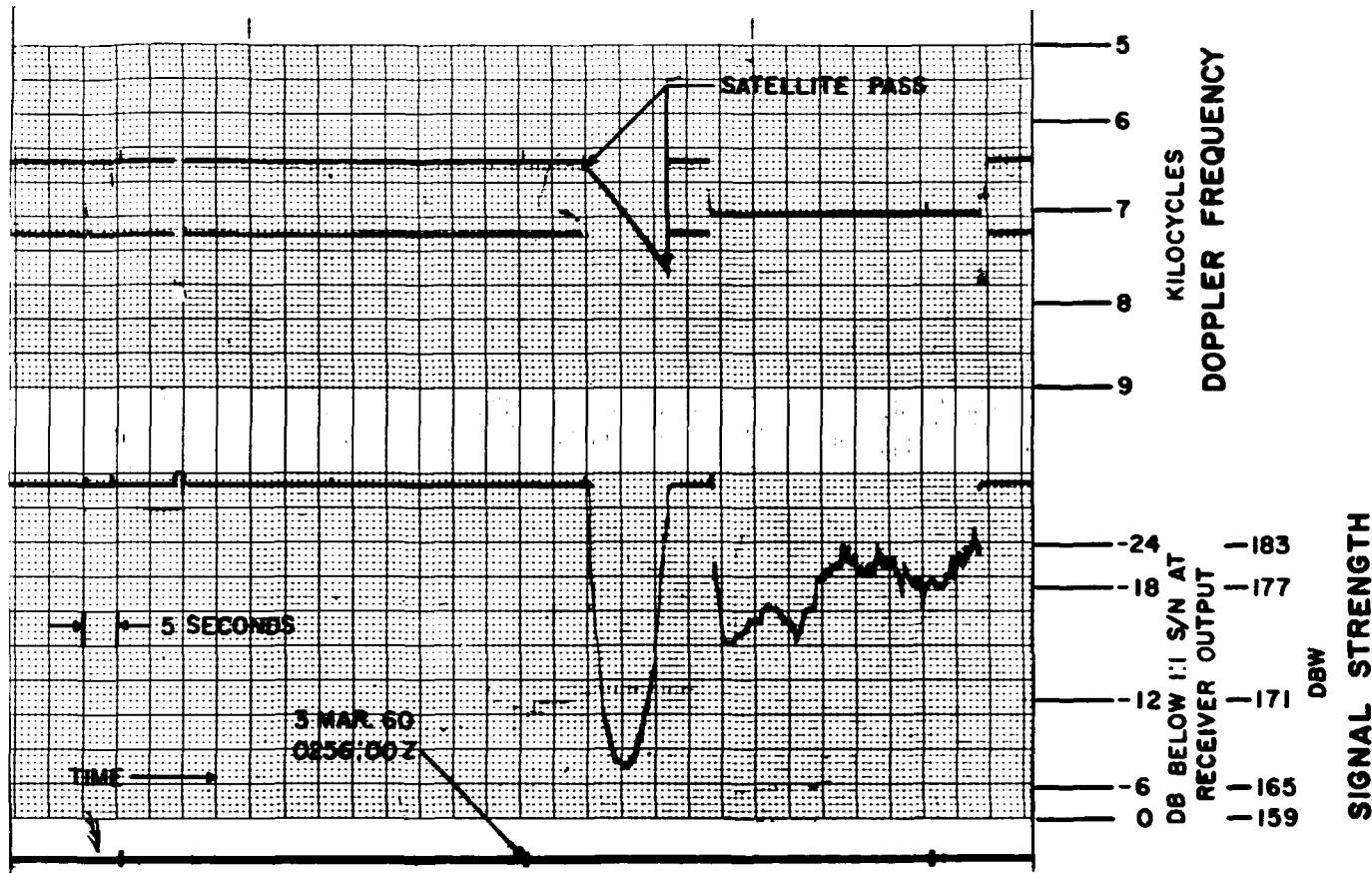


Fig. 16

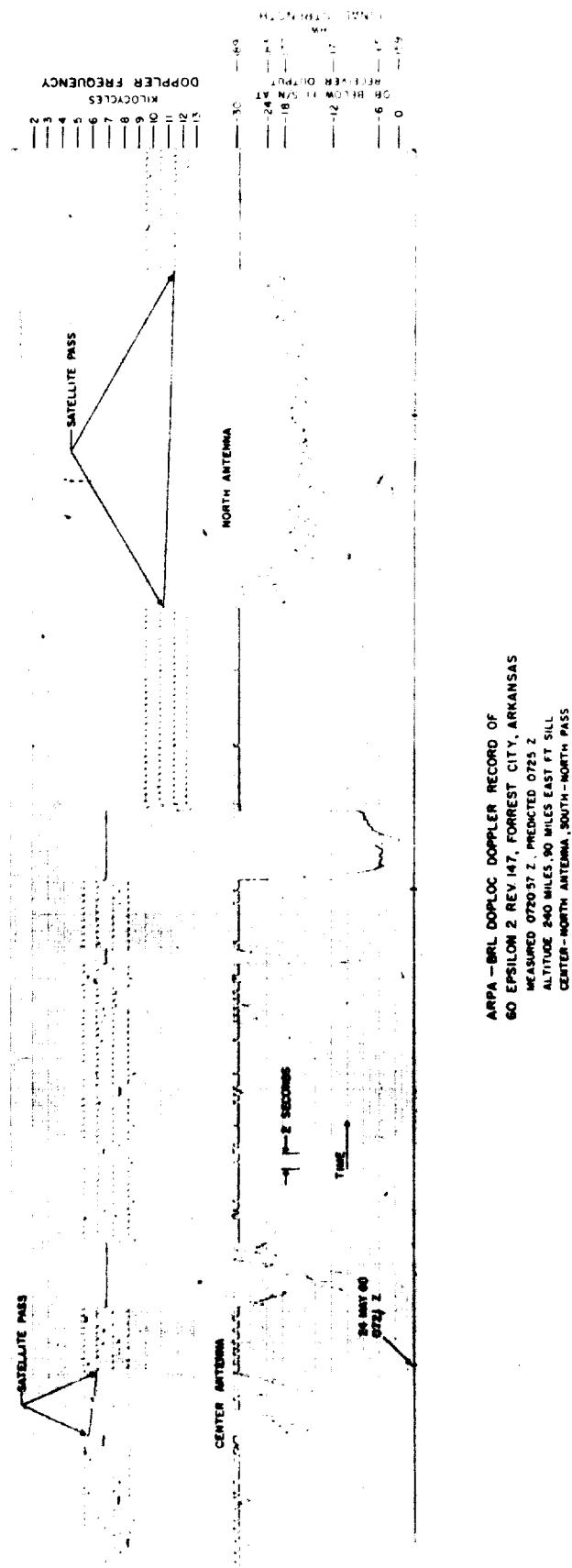
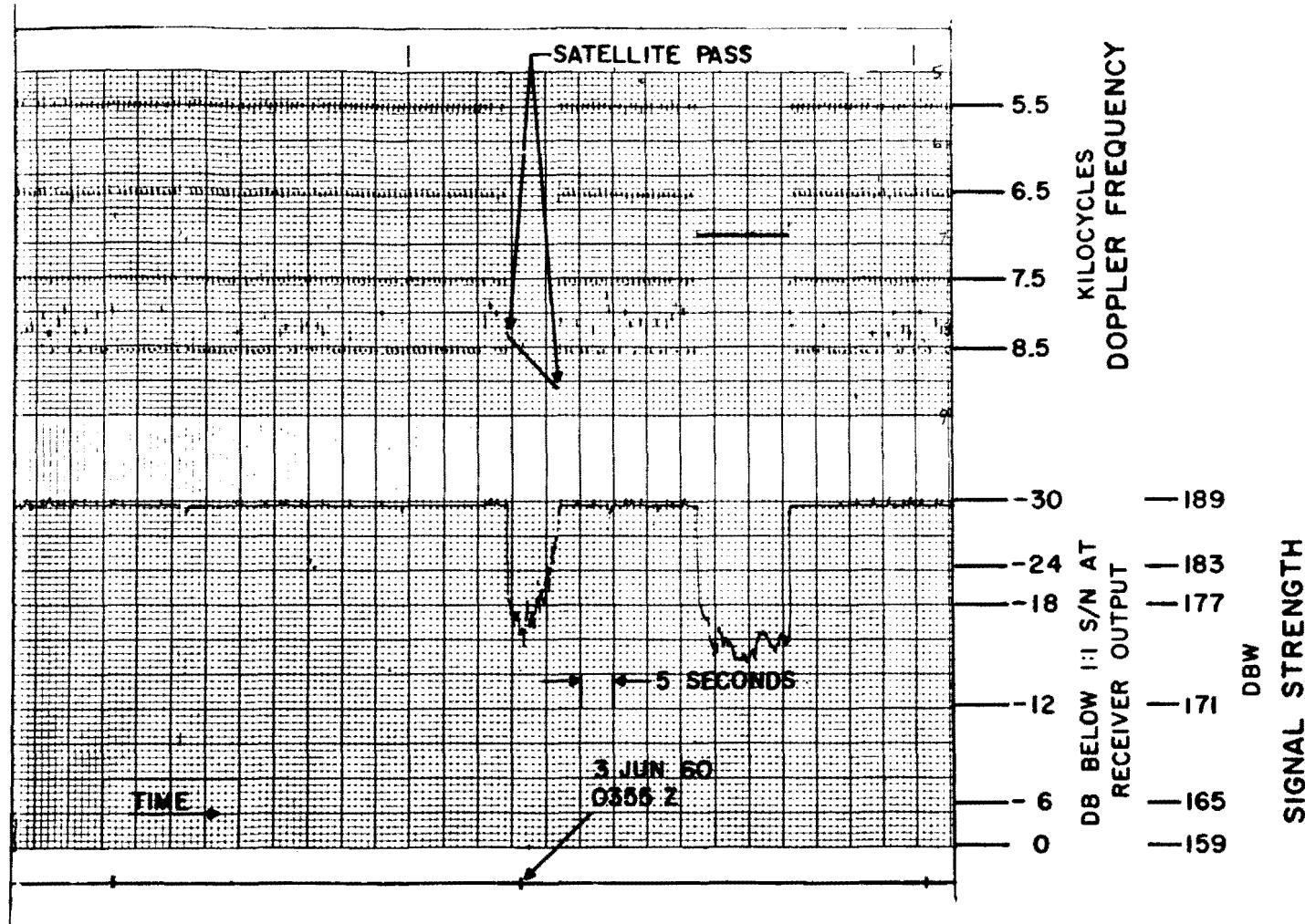
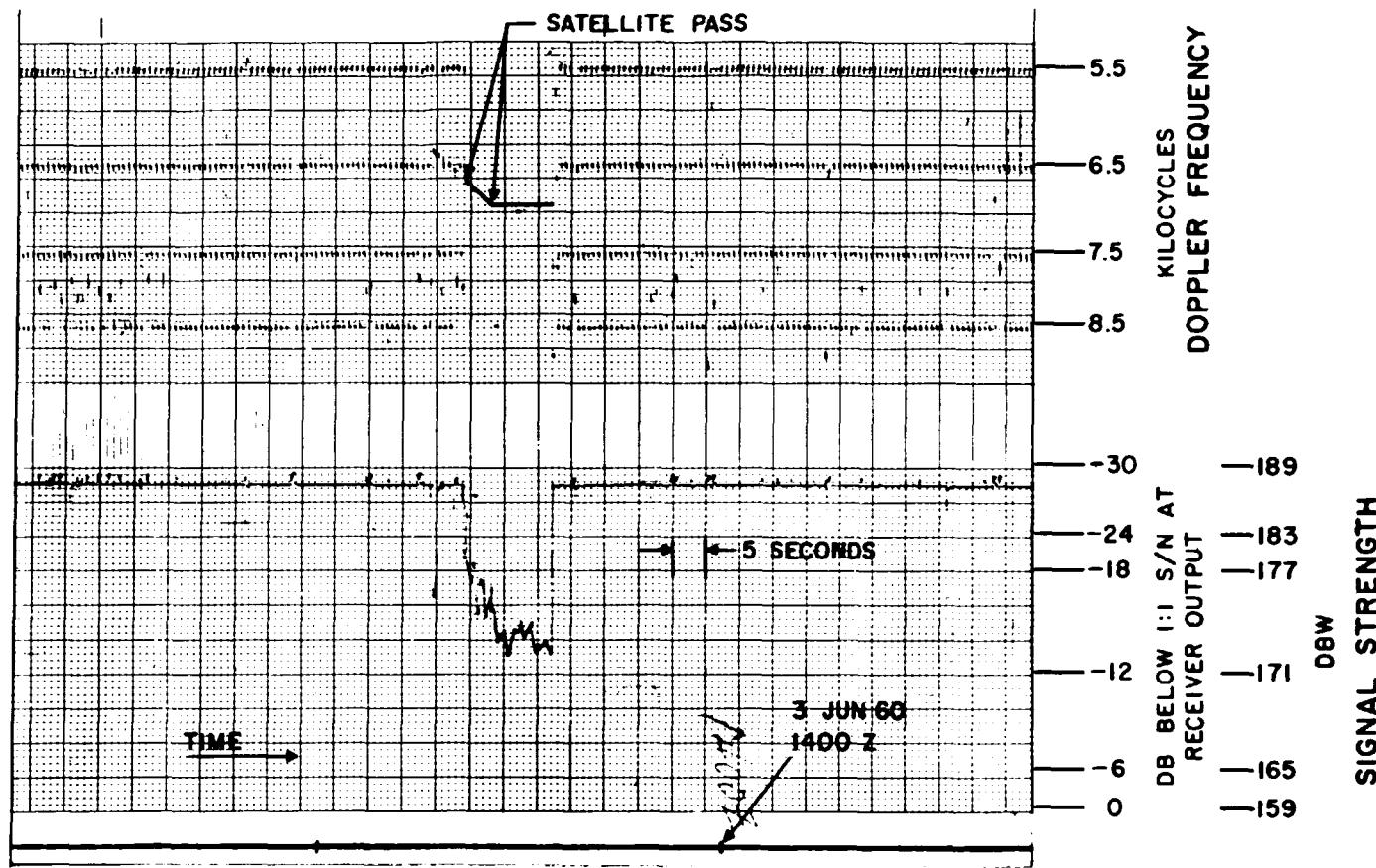


Fig. 17



ARPA-BRL DOPLOC DOPPLER RECORD OF
60 EPSILON 2 REV. 303, FORREST CITY, ARKANSAS
MEASURED 0354:58 Z, PREDICTED 0356 Z
ALTITUDE 213 MILES, 420 MILES EAST FT. SILL
CENTER ANTENNA, SOUTH-NORTH PASS

Fig. 18



ARPA - BRL DOPLOC DOPPLER RECORD OF
60 EPSILON 6 REV. 301, FORREST CITY, ARKANSAS
MEASURED 1359:22 Z, PREDICTED 1400 Z
ALTITUDE 233 MILES, 190 MILES EAST FT. SILL
CENTER ANTENNA, NORTH - SOUTH PASS

Fig. 19

59 גילה גולן 22

* ALTITUDE OF PASS IN MILES | - SATELLITE PASS | - FLAT

EIC 20 - E1 ATS AND SATELLITE PASSES 22 22 111X 60

13 SEPT. 59

		0100	0200	0300	0400	0500	0600
0000							
0600	59 e1-210*	0700	0800	0900	1000	1100	1200
1200	1300	1400	1500	1600	1700	1800	
1800	1900	2000	2100	2200	2300	2400	
14 SEPT. 59	58 82-430	59 e1-147					
0000		0100	0200	0300	0400	0500	0600
0600	1 59 e1-212	0700	0800	0900	1000	1100	1200
1200	1300	1400	1500	1600	1700	1800	
1800	1900	2000	2100	2200	2300	2400	
15 SEPT. 59							
0000		0100	0200	0300	0400	0500	0600
0600		0700	0800	0900	58 82-660	1000	1100
1200	1300	1400	1500	1600	1700	1800	58 82-432
1800	1900	2000	2100	2200	2300	2400	
16 SEPT. 59	59 e1-140						
0000		0100	0200	0300	0400	0500	0600
0600		0700	0800	0900	1000	1100	1200
1200	1300	1400	1500	1600	1700	1800	
1800	1900	2000	2100	2200	2300	2400	
17 SEPT. 59	59 e1-122†			59 e1-146			
0000		0100	0200	0300	0400	0500	0600
0600	1 59 e1-219	0700	0800	58 82-658	0900	1000	1200
1200	1300	1400	1500	1600	1700	1800	
1800	1900	2000	2100	2200	2300	2400	

* ALTITUDE OF PASS IN MILES

† - SATELLITE PASS

I - FLAT

† PASS RECEIVED BY DOPLOC

15 DEC. 59

0000	0100	0200	0300	0400	0500	0600
0600	0700	0800	58 82-492*	0900	1000	1100
1200	1300	1400	1500	1600	1700	1800
1800	1900	2000	2100	2200	2300	2400
16 DEC. 59						
0000	0100	0200	0300	0400	0500	0600
0600	0700	58 82-485	0800	0900	1000	1100
1200	1300	1400	1500	1600	1700	1800
1800	1900	2000	2100	2200	2300	2400
17 DEC. 59						
0000	0100	0200	0300	0400	0500	0600
0600	0700	58 82-482	0800	0900	1000	1100
1200	1300	1400	1500	1600	1700	1800
1800	1900	2000	2100	2200	2300	2400
18 DEC. 59						
0000	0100	0200	0300	0400	0500	0600
0600	0700	58 82-476	0800	0900	1000	1100
1200	1300	1400	1500	1600	1700	1800
1800	1900	2000	2100	2200	2300	2400
21 DEC. 59						
0000	0100	0200	0300	0400	0500	0600
0600	0700	0800	0900	1000	1100	1200
1200	1300	1400	1500	58 82-194	1600	1700
1800	1900	2000	2100	2200	2300	2400

* ALTITUDE OF PASS IN MILES

| - SATELLITE PASS

I - FLAT

75

FIG. 22 - FLATS AND SATELLITE PASSES, 15-21 DEC. 59

12 JAN. 60

	10	20	30	40	50	0100	10	20	30	40	50	0200	10	20	30	40	50	0300	10	20	30	40	50	0400	10	20	30	40	50	0500	10	20	30	40	50	0600	
0000	10	20	30	40	50	0100	10	20	30	40	50	0200	10	20	30	40	50	0300	10	20	30	40	50	0400	10	20	30	40	50	0500	10	20	30	40	50	0600	
0600	58 82-410*					0200		0800				0900						1000						1100							1200						
1200						1300						1400						1500						1600							1700						1800
1800						1900						2000						2100						2200							2300						2400
13 JAN. 60																																					
0000						0100						0200						0300						0400							0500						0600
0600						0700						0800						0900						1000							1100						1200
1200						1300						1400						1500						1600							1700						1800
1800						1900						2000						2100						2200							2300						2400
14 JAN. 60																																					
0000						0100						0200						0300						0400							0500						0600
0600						0700						0800						58 82-186†						0900							1000						1200
1200						1300						1400						1500						1600							1700						1800
1800	10	20	30	40	50	1900	10	20	30	40	50	2000	10	20	30	40	50	2100	10	20	30	40	50	2200	10	20	30	40	50	2300	10	20	30	40	50	2400	
15 JAN. 60																																					
0000						0100						0200						0300						0400							0500						0600
0600						0700						0800												0900							1000						1200
1200						1300						1400						1500						1600							1700						1800
1800						1900						2000						2100						2200							2300						2400
16 JAN. 60																																					
0000						0100						0200						0300						0400							0500						0600
0600						0700						0800						0900						1000							1100						1200
1200						1300						1400						1500						1600							1700						1800
1800	10	20	30	40	50	1900	10	20	30	40	50	2000	10	20	30	40	50	2100	10	20	30	40	50	2200	10	20	30	40	50	2300	10	20	30	40	50	2400	

* ALTITUDE OF PASS IN MILES

| - SATELLITE PASS

I - FLAT

77

FIG. 23 - FLATS AND SATELLITE PASSES, 12-16 JAN. 60

† PASS RECEIVED BY DOPLOC

31 MAR. 60

		(NO. DATA 0000-0600)																										
0000	10 20 30 40 50	0100	10 20 30 40 50	0200	10 20 30 40 50	0300	10 20 30 40 50	0400	10 20 30 40 50	0500	10 20 30 40 50	0600																
		58 82-158*																										
0600		0700																										
1200		1300																										
1800		1900																										
1 APR. 60		(NO. DATA 0000-1100)																										
0000	10 20 30 40 50	0100	10 20 30 40 50	0200	10 20 30 40 50	0300	10 20 30 40 50	0400	10 20 30 40 50	0500	10 20 30 40 50	0600																
0600		0700																										
1200		1300																										
1800		1900																										
4 APR. 60		(NO. DATA 0000-1400)																										
0000	10 20 30 40 50	0100	10 20 30 40 50	0200	10 20 30 40 50	0300	10 20 30 40 50	0400	10 20 30 40 50	0500	10 20 30 40 50	0600																
0600		0700																										
1200		1300																										
1800		1900																										
5 APR. 60		(NO. DATA 0200-1000)																										
0000	11 12 13 14 15	0100	11 12 13 14 15	0200	11 12 13 14 15	0300	11 12 13 14 15	0400	11 12 13 14 15	0500	11 12 13 14 15	0600																
0600		0700																										
1200		1300																										
1800	10 20 30 40 50	1900	10 20 30 40 50	2000	10 20 30 40 50	2100	10 20 30 40 50	2200	10 20 30 40 50	2300	10 20 30 40 50	2400																
6 APR. 60		(NO. DATA 0400-1300)																										
0000	11 12 13 14 15	0100	11 12 13 14 15	0200	11 12 13 14 15	0300	11 12 13 14 15	0400	11 12 13 14 15	0500	11 12 13 14 15	0600																
0600		0700																										
1200		1300																										
1800		1900																										

* ALTITUDE OF PASS IN MILES

| - SATELLITE PASS

I - FLAT

79

FIG. 24 - FLATS AND SATELLITE PASSES, 31 MAR. - 6 APR. 60

† PASS RECEIVED BY DOPLOC

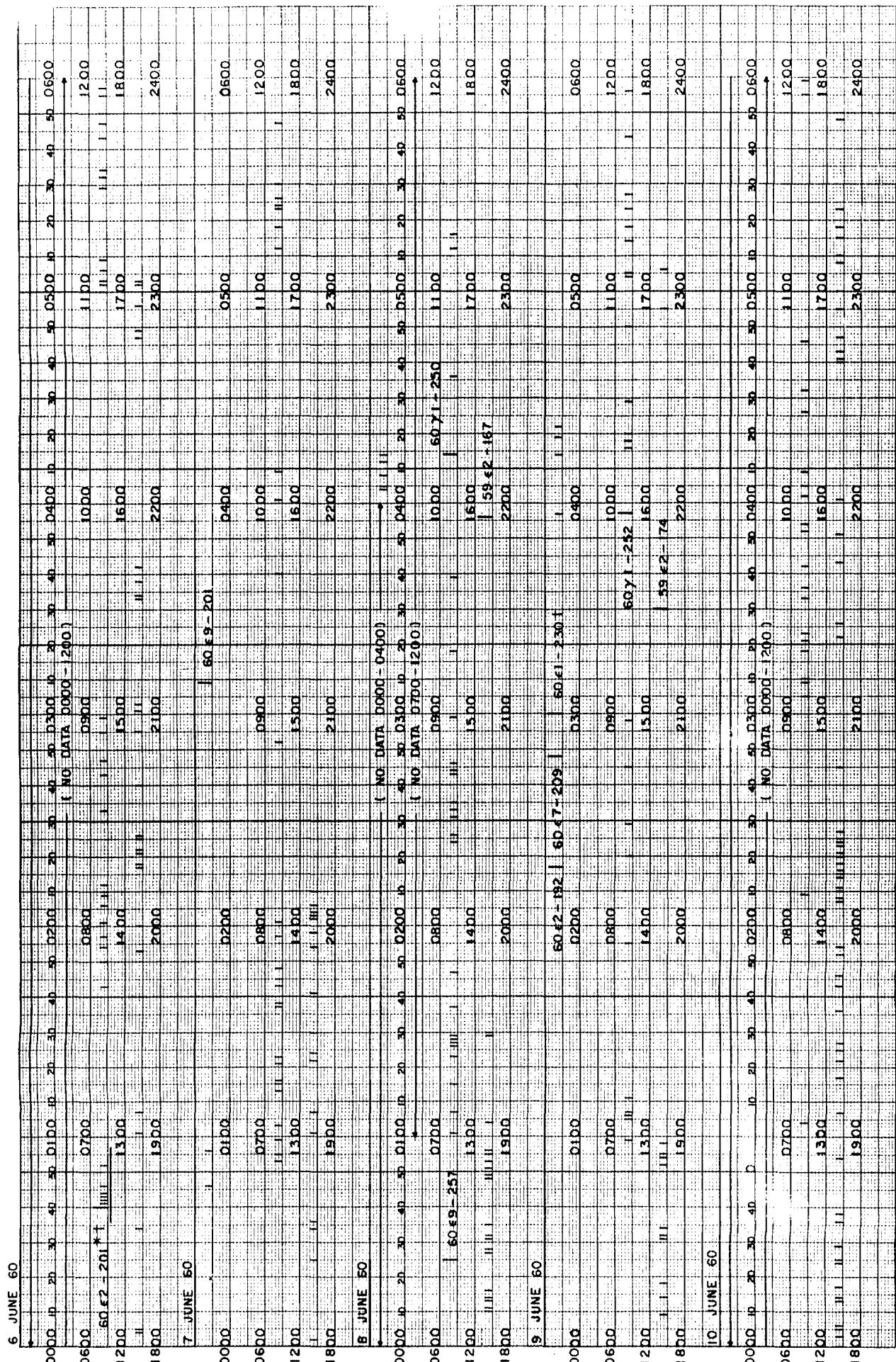
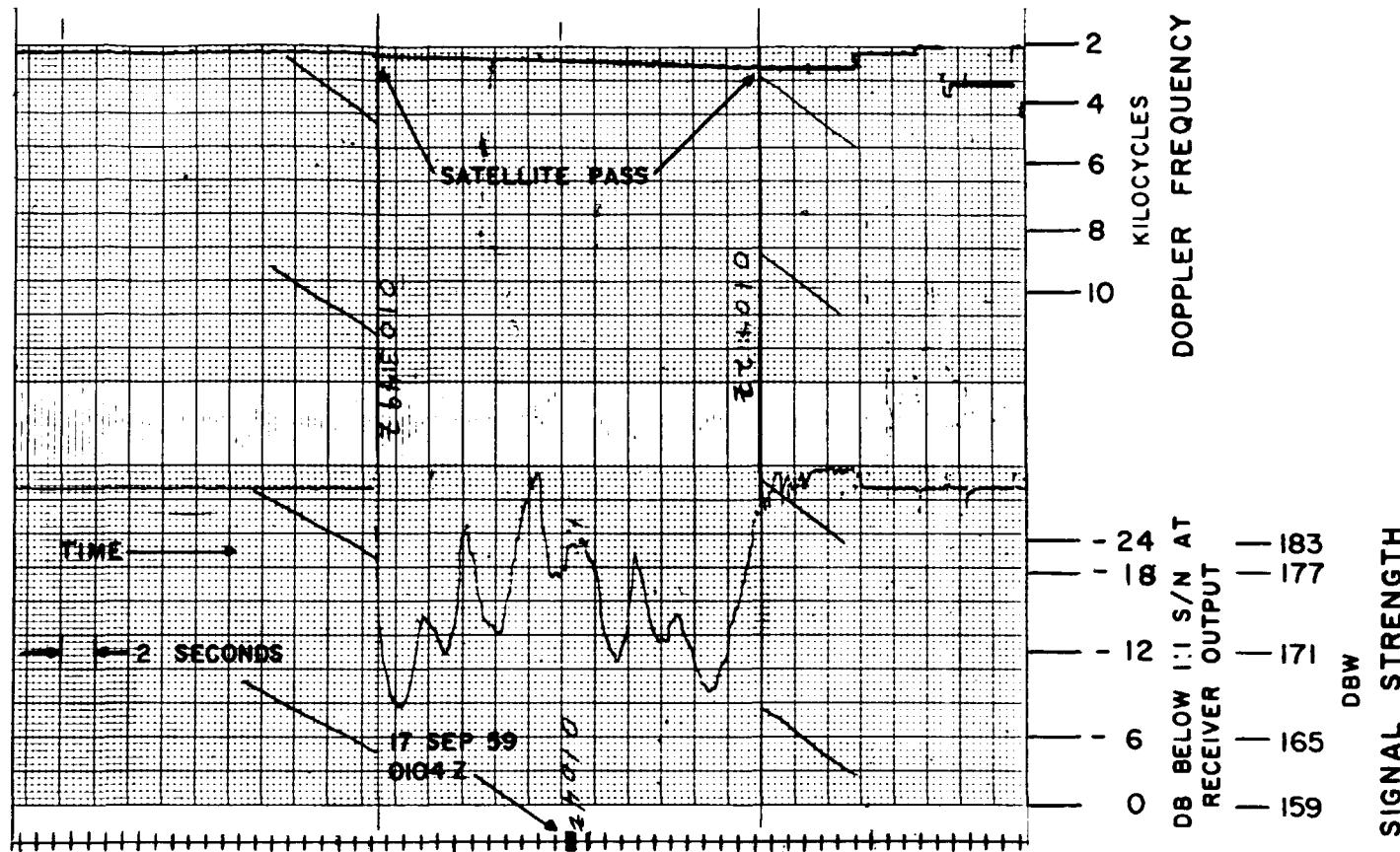
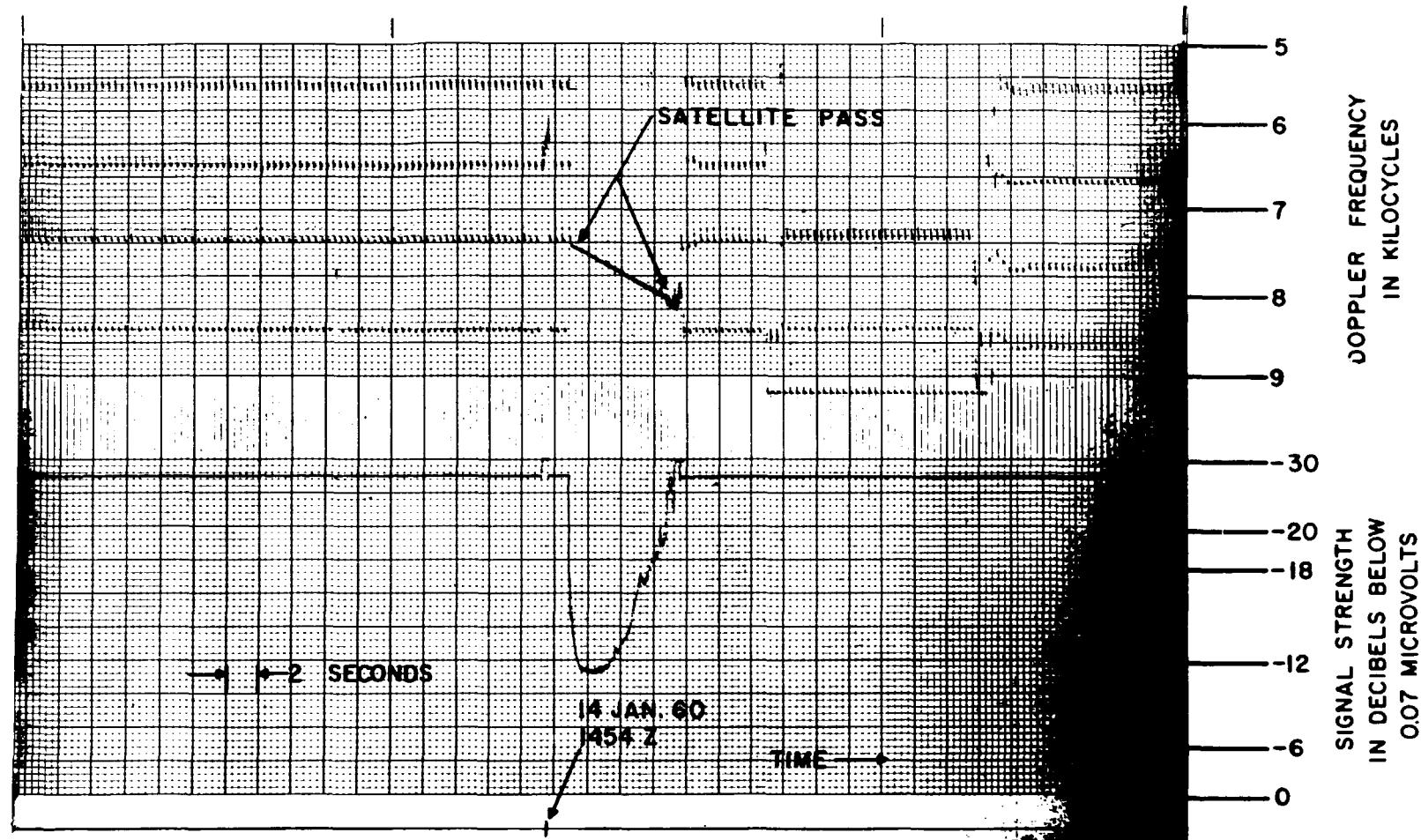


FIG. 25 - FLATS AND SATELLITE PASSES, 6 - 10 JUNE 60

* ALTITUDE OF PASS IN MILES | - SATELLITE PASS ! - FLAT
 † PASS RECEIVED BY DOPLOC

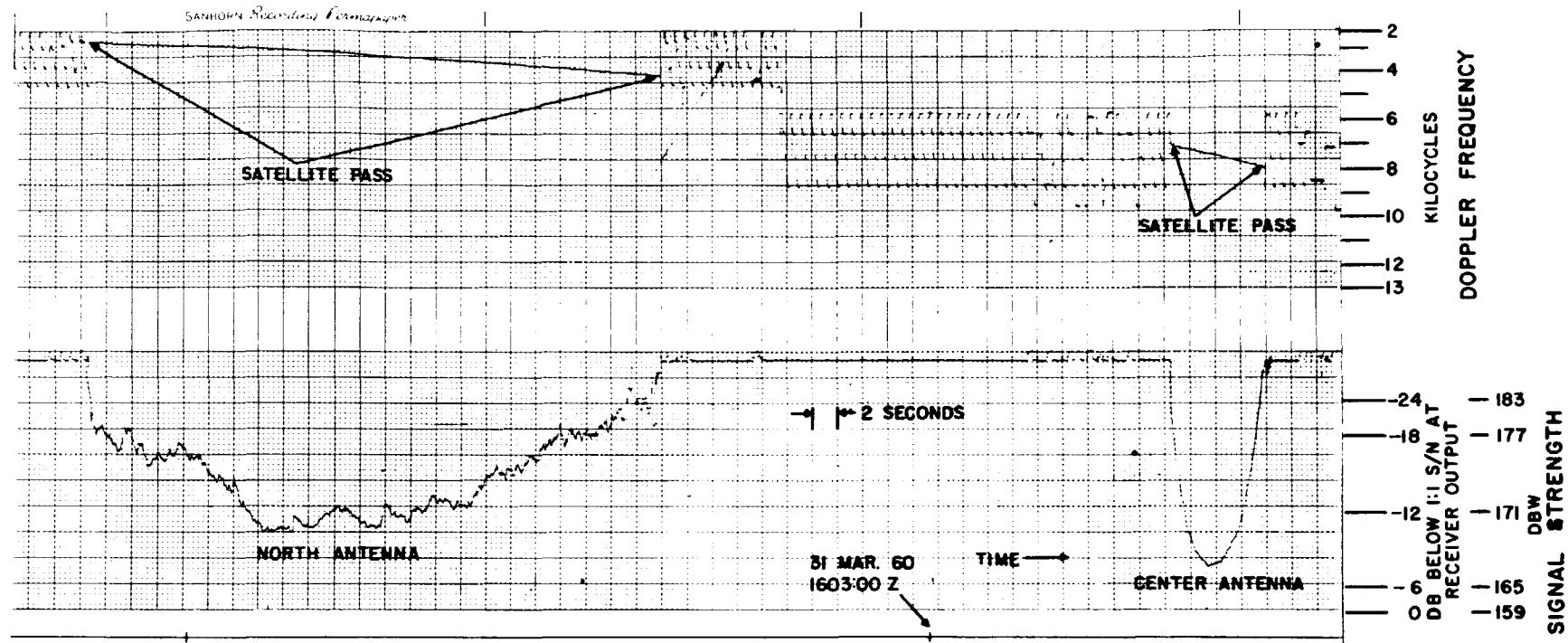


ARPA - BRL DOPLOC DOPPLER RECORD OF
59 EPSILON REV. 532, FORREST CITY, ARKANSAS
MEASURED 0103:49Z, PREDICTED 0106Z
ALTITUDE 122 MILES, 32 MILES WEST FT. SILL
SOUTH ANTENNA, SOUTH - NORTH PASS



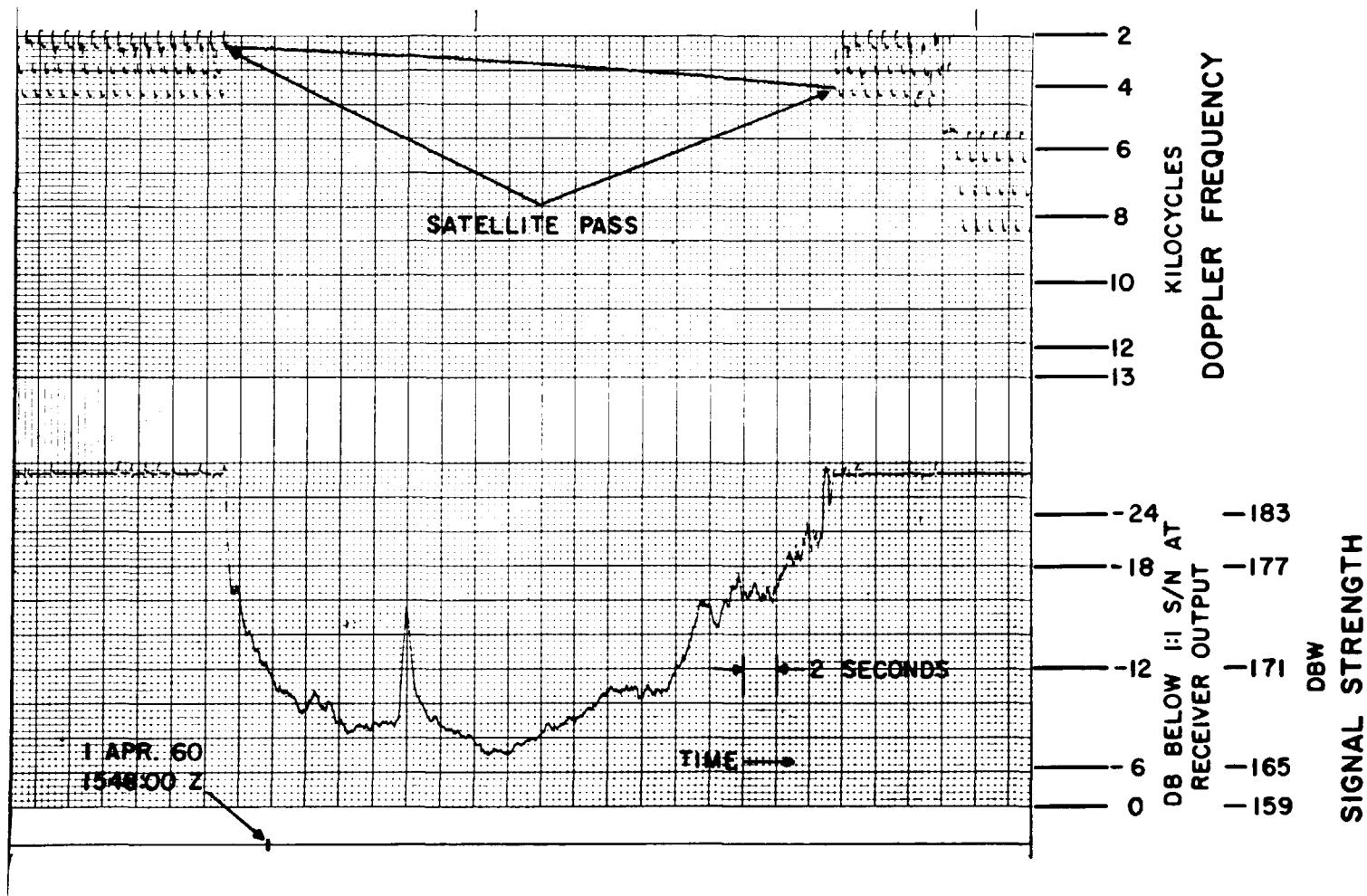
ARPA - BRL DOPLOC DOPPLER RECORD OF
58 DELTA REV. 8734, FORREST CITY, ARKANSAS
MEASURED 1454:02 Z, PREDICTED 1452 Z
ALTITUDE 186 MILES, 326 EAST FT. SILL
CENTER ANTENNA, NORTH-SOUTH PASS

Fig. 27



ARPA - BRL DOPLOC DOPPLER RECORD OF
 58 DELTA REV. 9943, FORREST CITY, ARKANSAS
 MEASURED 1601:53 Z, PREDICTED 1602 Z
 ALTITUDE 105 MILES, 310 MILES EAST OF FT. SILL
 NORTH AND CENTER ANTENNAS, NORTH-SOUTH PASS

Fig. 28



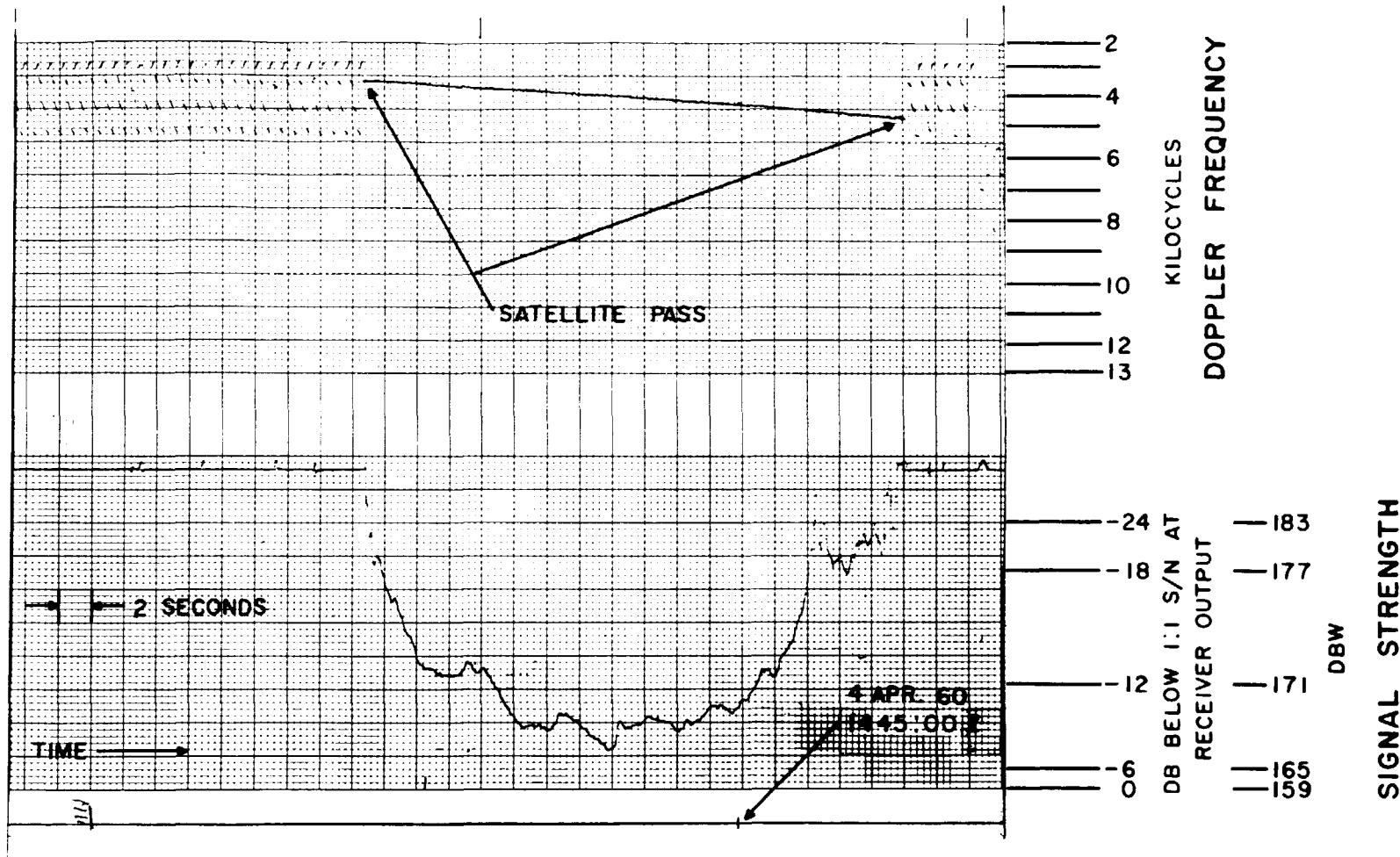
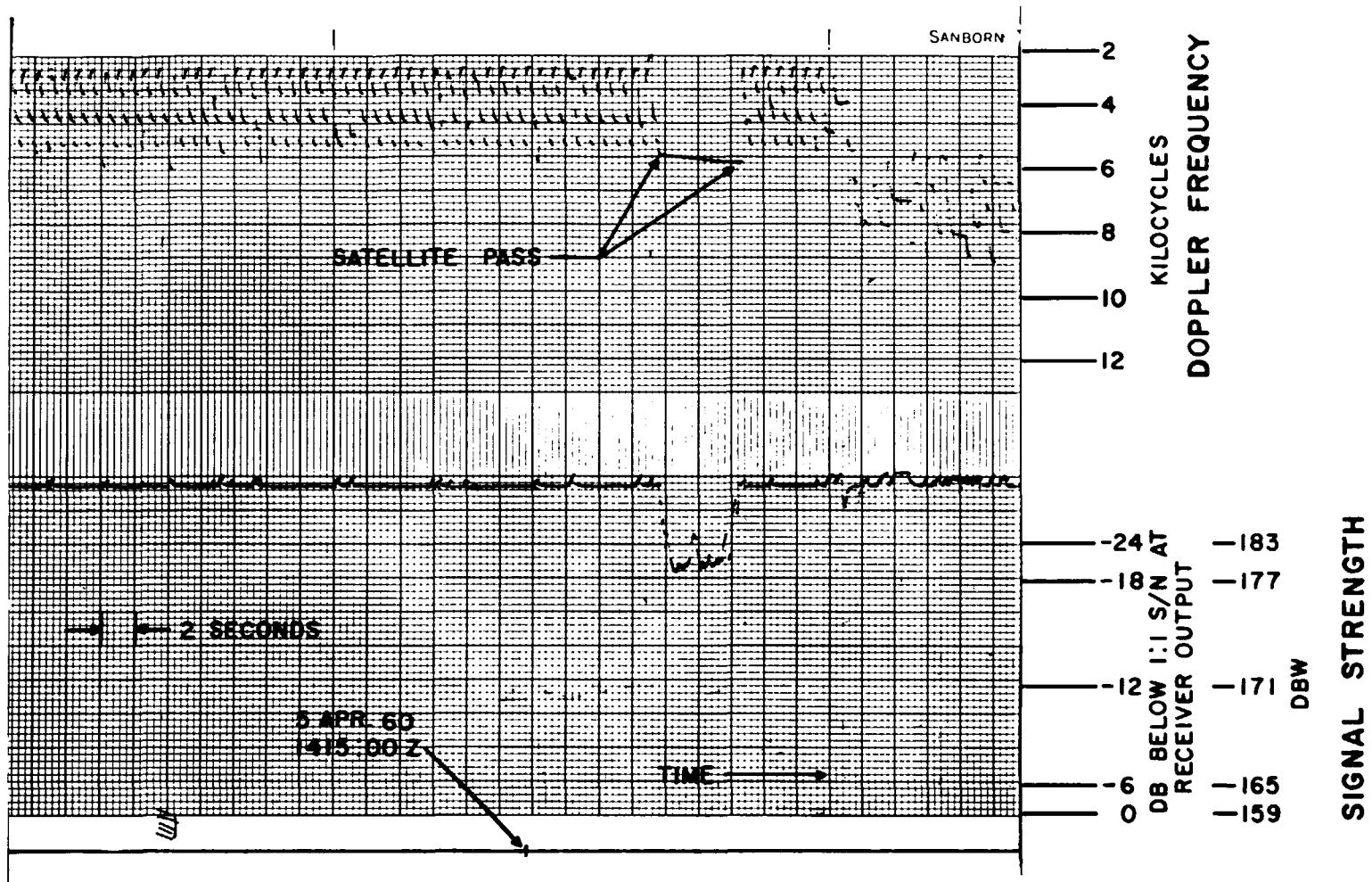
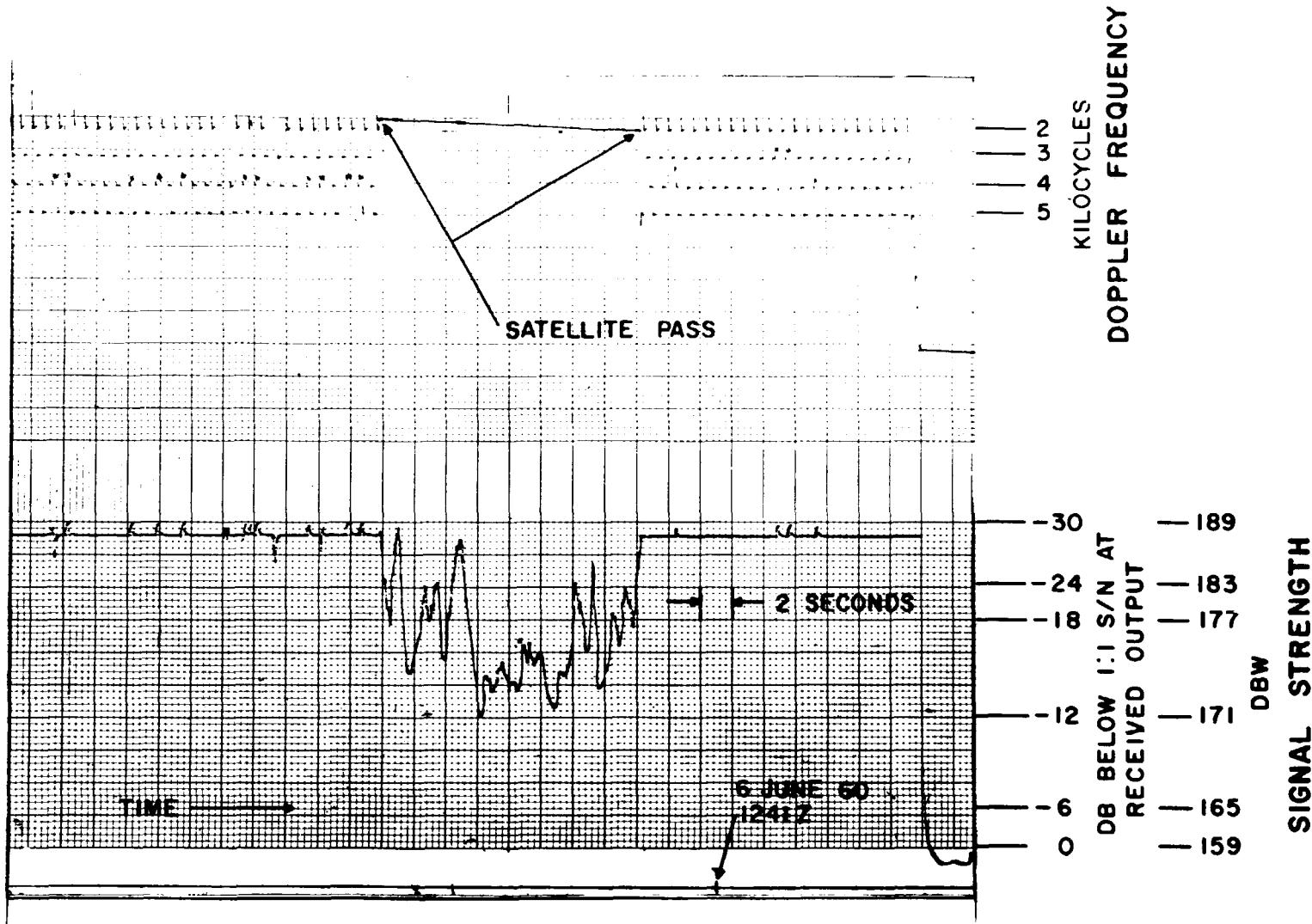


Fig. 30





ARPA - BRL DOPLOC DOPPLER RECORD OF
60 EPSILON 2 REV. 356, FORREST CITY, ARKANSAS
MEASURED 1240:39 Z, PREDICTED 1238 Z
ALTITUDE 201 MILES, 30 MILES EAST FT. SILL
NORTH ANTENNA, NORTH - SOUTH PASS

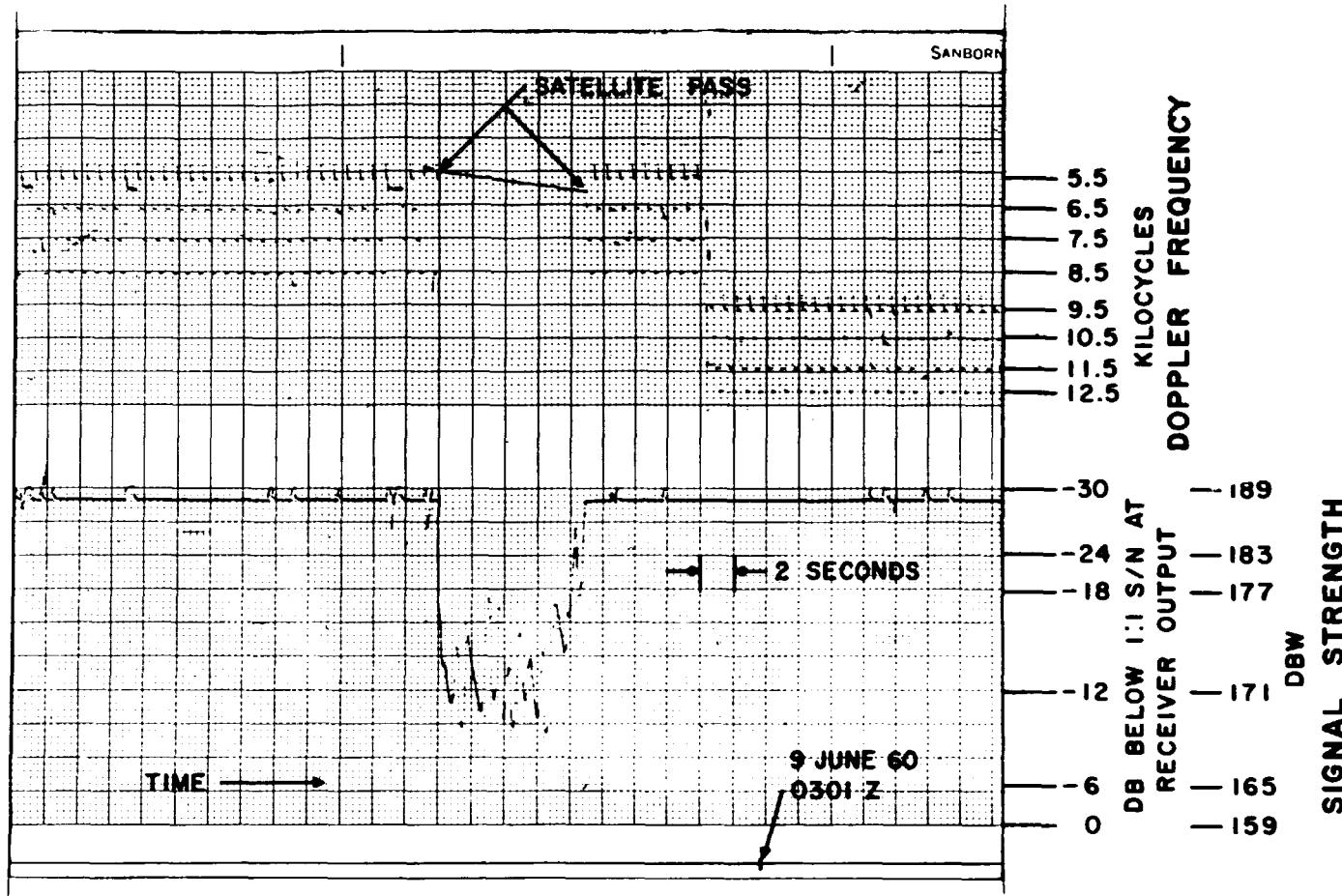


Fig. 33

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